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Rev #: 0
OCA file #: 90
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LAI J S CE

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Title: DEVELOPMNT OF LAB RUTTING RESISTANCE TEST METHOD FOR ASPHALT MIXES/SCEP-88-66

PROJECT ADMINISTRATION DATA

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 05/03/90

Project No. E-20-830 Center No. T5172-0A0

Project Director LAI J S School/Lab CE

Sponsor GA DEPT OF TRANSPORTATION/

Contract/Grant No. 14 Contract Entity GTRC

Prime Contract No.

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Effective Completion Date 890814 (Performance) 891014 (Reports)

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Final Invoice or Copy of Final Invoice	Y	
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Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
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Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
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NOTE: Final Patent Questionnaire sent to PDPI.

Contract Research

GaDOT Research Project No. 8717

FINAL REPORT

DEVELOPMENT OF A LABORATORY RUTTING RESISTANCE TESTING METHOD FOR ASPHALT MIXES

by

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Prepared for

Georgia Department of Transportation
Office of Materials and Research

August, 1989

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ABSTRACT

A loaded wheel testing machine (LWT machine) was used successfully in the previous studies to evaluate the rutting characteristics of asphalt mixes. The objective of this study was to modify and improve the machine and the sample preparation method and to develop a testing procedure for using this machine.

The improvements and modifications made to the LWT machine includes the development of an environmental chamber attached to the machine for maintaining a constant elevated temperature for the test sample during the rutting test and the development of a preheating box for preconditioning the test sample to the prescribed elevated temperature. The temperature of the beam samples can be heated and maintained up to 125^{o}F at ± 1^{o}F variation. Other modifications and improvements were made for the control and operation of the testing machine. Another major effort was to develop a beam sample preparation method by static compression using a universal testing machine.

CHAPTER 1

INTRODUCTION

Rutting on asphalt pavement has become more serious as the wheel loads and tire pressure of truck traffic on highways have increased continuously. Rutting reduces road serviceability and drive comfort and also creates the problem of hydroplaning due to accumulation of water in rutting paths. Methods to eradicate rutting on wheel paths usually involve asphalt concrete overlay. This rehabilitation process is costly and there is no assurance that the overlayed pavements will not rut again.

An asphalt pavement can develop rutting due to either inadequate structural capacity as a result of improper design, or improper construction practices, or lack of stability of the asphalt mix used in the pavement surface. Current available methods for analyzing the pavement system responses and predicting pavement rutting such as [1,2] have the ability to design a pavement structure with adequate resistance to rutting. Rutting occurs on asphalt pavement due to lack of stability and poor resistance to deformation of the asphalt mix itself must be mitigated, by having a better asphalt mix design procedure through which asphalt mixes with better rutting resistance can be obtained.

Marshall mix design method and Hveem mix design method are two commonly used methods for the design of asphalt mixes. Although asphalt mixes obtained according to these two methods can eliminate extremely unstable mixes, there is no assurance that an asphalt mix with its properties satisfying the design criteria of either one of these methods will not develop rutting under normal traffic conditions. Recent studies [3,4,5] by Lai demonstrated this inability of the Marshall method to assess the rutting potential of asphalt mixes. Many testing methods have been proposed in an attempt to improve the predictability of rutting potential of asphalt mixes. These include the triaxial repeated load test, and the creep test [3]. Also, a simplified rutting test method using a loaded wheel testing machine was proposed by Lai [3,4,5].

In a recent study conducted by Lai [3] for GaDOT, it has demonstrated that the loaded wheel testing machine is capable of evaluating the rutting characteristics of asphalt concrete. Results of the asphalt mixes tested using loaded wheel testing method were more compatible with the rutting characteristics normally experienced in asphalt pavements under vehicular loading than the characteristics of the permanent deformation of the same asphalt mixes tested under the triaxial repeated load test and the creep test. In the second study [4], the loaded wheel testing machine was used to assess the rutting potential of GaDOT Type B asphalt mixes and the six different modified mixes using aggregates from three different sources. The mixes used different fillers which have different gradation and particle shape and size distribution. One of the mixes also contained polymer modifier. Although all the twenty-one asphalt mixes met the Marshall mix criteria, they exhibited significantly different rutting characteristics when tested under the loaded wheel testing machine. From these test results certain modified mixes which have the potential to give better resistance to rutting were identified.

In the third study [5], the same test method was used to evaluate rutting potential of six asphalt mixes for potential use in base course. The gradation of the mixes varied in both the maximum aggregate size and the fine aggregate portion. Again, the results from the loaded wheel test showed significant difference in rutting resistance among the mixes, even though all the mixes satisfied Marshall mix criteria.

These three studies have shown that the loaded wheel testing machine offers a simple testing procedure which has the capability to assess the rutting characteristics of asphalt mixes. It seems that this testing procedure has the potential to be used in conjunction with the Marshall mix design method to design asphalt mixes with better rutting resistance. It is envisioned that under this approach, a laboratory asphalt mix design procedure will consist of a standard Marshall mix design in which one or several mixes which all satisfy Marshall design criteria are first obtained. Samples from the mix(es) are then prepared and tested according to the loaded wheel testing procedure. Results from the test will then be used to assess if any of the mixes which meet Marshall design criteria will offer adequate rutting resistance according to the yet to be established rutting resistance criteria.

Therefore the objective of this proposed investigation was to further modify and improve the loaded wheel testing machine and the sample preparation method and to develop a testing procedure for using this equipment.

CHAPTER 2

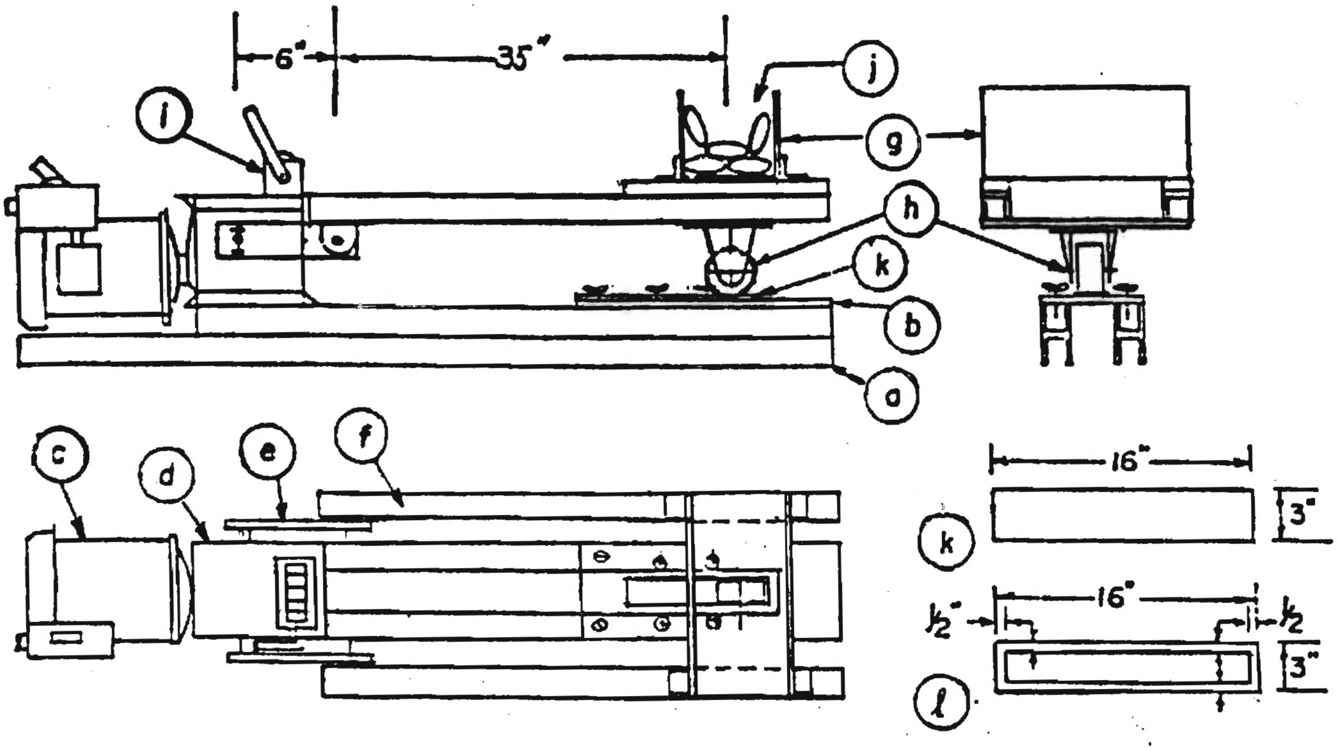
MODIFICATION OF LOADED WHEEL TESTING MACHINE

The original version of the loaded wheel tester (LWT) was used by the GaDOT Materials Testing Laboratory for testing of asphalt slurry seals. This machine was developed by Benedict(1). A similar machine has been used elsewhere to evaluate the rutting potential of asphalt concrete [6,7]. The original LWT was modified as reported in the previous studies [3,4] and has been further improved in the course of this proposed investigation to make it more adaptable for a routine laboratory testing equipment. In the following sections the original version of the LWT and various modifications on the equipment are presented.

2.1 Description of the Original Loaded Wheel Tester

The main components of the original LWT are shown schematically in Figure 1. The main features of this equipment are a loaded wheel (h) driven through a 12 in. reciprocating stroke driving crank and connecting frame (e.d f) by a 1/3 hp, 1750 rpm motor (c) which is reduced 40:1 to give 44 cycles per minute of repeated action. The wheel, 1 in. wide and 3 in. diameter is made of hard rubber. A weight holding box (g) for holding lead shot (j) is mounted on the connecting frame directly atop the wheel for applying loading to the wheel. The test sample, typically 3 in. wide by up to 1 in. thick and 16 in. long is molded in the specimen mold (l) which is secured on mounting plate (k). The total number of cycles (one cycle consists of two passes of the loaded wheel over the test sample) is registered in the resetable counter (i).

Note: Benedict Slurry Seal, Inc., 320 Nrothview Rd., Dayton, Ohio 45419.



Description of Main Components

a. Feame of adjustable steel channel
b. Mounting plate for specimens
c. 1/3 HP, 1750 RPM motor
d. 40:1 horizontal double output shaft gear reducer
e. Drive cranks, 6 in. radius
f. Driven connecting arms
g. Weight box
h. Caster with 3" diameter x 1" rubber tire
i. Resetable revolution counter
j. weights
k. Specimen mounting plate
l. Specimen mold

Figure 1. Loaded Wheel Tester (origional machine)

2.2 Description of Modified Loaded Wheel Tester

Modifications and improvements made to the original LWT are primarily in the following areas: loading wheel, temperature control, sample mounting, operation control and rut profile measurement. Before discussing the details of various modifications and improvements, which will be presented in the subsequent sections in this chapter, the overall features of the modified LWT machine are presented in the remainder of this section.

Figure 2 shows the main features of the modified LWT machine. The 3 in. x 3 in. x 15 in. beam sample (A) is placed in the sample holding mold (B). The beam sample and the sample holding mold can be seen more clearly in Figure 3. The base of the sample holding mold includes a removable 3 in. x 15 in. x 1/2 in. steel plate to simulate a rigid base course condition. This steel plate can be replaced with an equal thickness of a resilient rubber pad to simulate a flexible base. The sides and ends of the sample are partially confined by the steel angles. The details of the beam sample holding mold can be seen from Figure 3. A pressurized rubber hose (C), also can be seen from Figure 3, is placed on top of the sample and is partially restrained at the ends. Except for the loading wheel (D) shown in Figure 2, the other components of the loading system which consists of a 1/3 hp motor (G), a 12 in. reciprocating stroke arms (E and F) and the weight holding box (H) are the same as the original LWT machine. In addition to the original equipped resetable mechanical counter (I) for recording the number of repetitions, a photorelay (J) which connected to an electric counter on top of the environmental chamber lid was installed so that the number of cycles during the test can be directly read when the environmental chamber lid is covered over the entire testing machine. The entire testing machine is enclosed in an environmental chamber which can maintain a constant

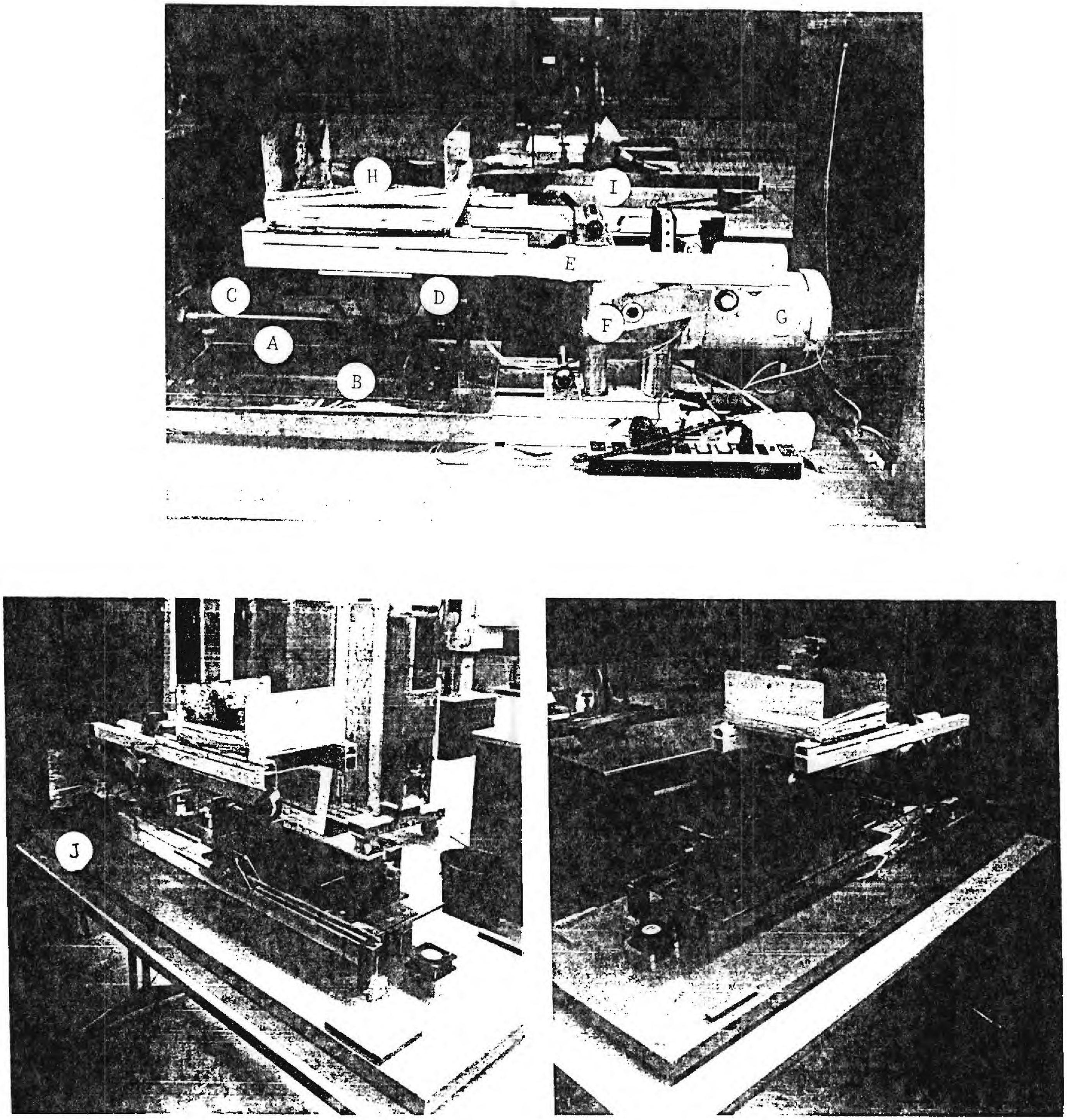


Figure 2. Modified Loaded Wheel Tester

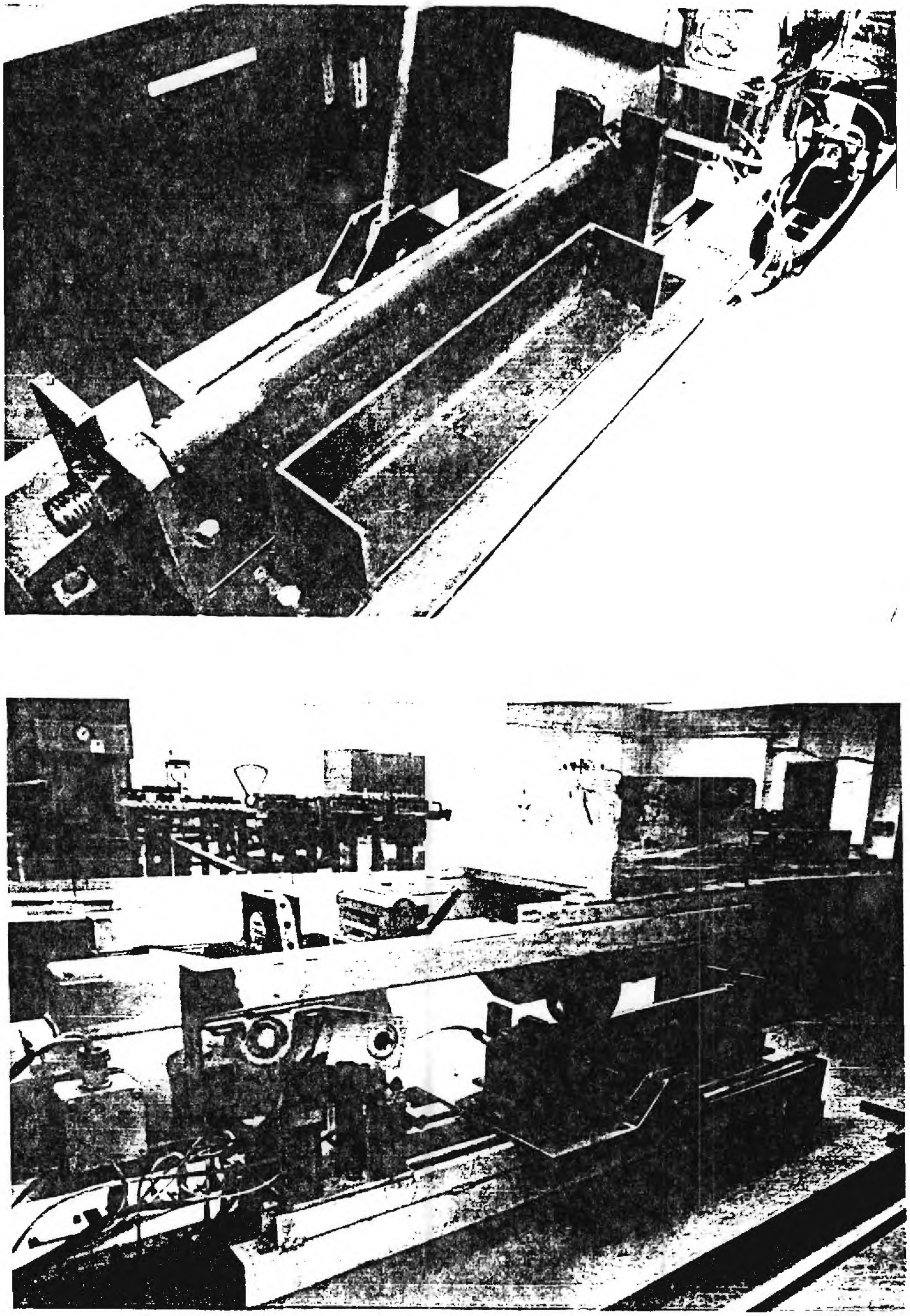


Figure 3. Linear Tube Loading System

temperature of up to 120^{o}F throughout the test period. The details of the environmental chamber and the preheating box (for preheating the test samples) are described in Section 2.4 and 2.5. Other modifications including the safety shut-off switches and rutting profile measuring device are described in Section 2.6.

2.3 Loading Wheel

The original loading wheel was 3 in. diameter by approximately 1 in. wide and was made of aluminum and was fitted with a hard rubber tire. This was considered to be inadequate because it could not control the pressure exerted on the asphalt beam specimen. The hard rubber tire would exert nonuniform contact pressure on the surface of an asphalt concrete sample, particularly for the coarser mixes. It was decided that this hard rubber tire should be replaced with an inflatable tire.

The first attempt was to look for an off-the-shelf small tire of about 1 in. wide with tire pressure inflatable up to 120 psi. We were unable to identify a suitable small tire which would meet the performance requirements. It was decided then to develop a loading wheel with the specified characteristics in the laboratory.

The first version developed was an 8 in. diameter aluminum wheel with a 1 in. diameter high pressure rubber hose wrapped around the rim of the wheel. The hose could be pressurized and maintained to a controlled pressure up to 100 psi through a 120 psi air pressure system and a pressure regulator. This wheel assembly was fitted on the LWT machine along with other necessary modifications on the machine to make the system compatible. Several preliminary rutting tests of up to 5000 cycles for each test were performed on 3 in. x 3 in. x 15 in. asphalt beam samples. The wheel assemblage itself was performed satisfactory with pressure in the hose kept relatively constant. There were several problems observed during the tests. The reciprocating action of the loaded wheel occurred at the end of each stroke causing the rubber hose to generate excessive skidding against the rough surface of the sample near the ends of the stroke which in turn cause excessive wear of the rubber hose and more importantly develop excessive rutting on the asphalt concrete samples near the ends of the beam. Furthermore, due to excessive ruts developed there, the wheel had the tendency to push instead of just roll along the wheel path near these regions. Shoving became evident along these regions and slowly progress toward the center. Also, in the middle region of the beam, which was considered to be free of the end effects, the rutting along the wheel path was very uneven. This problem, we believed, was primarily due to the relative small contact area of the wheel on the beam sample surface with respect to the maximum aggregate size. Initially, the deformation induced along the wheel path on the beam sample surface was slightly nonuniform due to presence of large aggregates near the surface at some positions along the wheel path. With a small and relatively concentrated wheel load applied repetitively, the nonuniform deformation tended to be accentuated as the repeated loading progressed and resulted in ridges and valleys developed along the wheel path. This nonuniform rutting along the wheel path was particularly worse on the coarser mixes, such as base course mixes. For the above reasons, this version of the wheel assemblage was abandoned.

To overcome the problems described above, a different concept of generating moving wheel load, which was a radical deviation from the conventional ways of generating moving wheel load was conceived. This concept of generating moving wheel load consisted of a linear flexible tube, made of a high pressure rubber hose, and a 3 in. diameter aluminum wheel, see Figure 3. The rubber hose was pressurized to the prescribed pressure and was placed stationally on top of the asphalt concrete specimen. The hose was loosely held in position on both ends by end clamps to maintain the longitudinal alignment along the center of the beam. The concave shape of the rim would keep the aluminum wheel on top of the rubber hose. The aluminum wheel was attached to the reciprocating arm of the machine. During the rutting test the loaded aluminum wheel was riding along the pressurized rubber hose and at the point of contact generated certain contact pressure on the surface of the beam sample.

The linear tube concept was tested and the performance was found to be quite satisfactory. It was found that the excessive rutting at both ends of the asphalt concrete sample was substantially reduced. Also, nonuniform rutting observed previously along the wheel path in the middle region of the test sample was also reduced. Since the skidding action due to reverse movement of the wheel occurred between the smooth aluminum wheel and the top side of the rubber hose, the sample which was in contact with the bottom side of the hose experienced substantially less skidding action and therefore, the excessive rutting developed around these regions previously observed was substantially reduced. The magnitude of rutting at these regions was still greater than that at the middle region. This was attributable to the longer total duration of loading imposed at these regions than at the middle region due to the reverse movement of the wheel at the end of the reciprocating action of the machine.

Because of the novelty of the linear tube loading concept, there were some questions yet to be answered. One of them was regarding the nature of the contact pressure exerted on the test specimen. The other one was regarding the effect of the stiffness of the rubber hose on the rutting of asphalt samples.

In the previous studies a relatively flexible type of rubber hose was used. Usually after one rutting test, the side of the hose in contact with the asphalt sample became quite rough. In the second test, the hose was rotated 180 degrees. The hose was replaced after the second test. Out of all the rutting tests conducted in the previous studies, only on one occasion did the rubber hose fail. In order to extend the useful life of the rubber hose, a stiffer type of rubber hose was tested in the course of this study. This stiffer rubber hose has 1.18 in. outside diameter and 0.75 in. inside diameter and has two plys of reinforcement along the hoop direction. Over 20 rutting tests were run using the same stiffer hose and the hose did not show any sign of deterioration.

It is conceivable that difference in the stiffness of the rubber hose could affect the test results. To evaluate this effect, the imprints of the contact areas between the rubber hose and the asphalt beam sample were made for the two different types of the rubber hose and at two loading levels, see Figure 4. These imprints are retraced and are shown in Figure 5. The imprints for the two types of rubber hose are indeed different. At 100 lbs. of wheel load, the flexible hose shows a wider contact area than that of the stiffer hose. This would indicate that the stiffer hose would exert a higher contact pressure on the beam sample than the flexible hose would. The actual distribution of the contact pressure on the beam sample is highly nonuniform and cannot be determined directly from the shapes of the imprint alone. Aside from using direct measurements of the contact pressure between the rubber hose and the sample surface within the contact area, indirect calculation of the actual pressure distribution within the contact

(A) Flexible Hose, 50 lb.

(B) Flexible Hose, 100 lb.

(C) Rigid Hose, 50 lb.

(D) Rigid Hose, 100 lb.

Figure 4. Imprints of the Rubber Hose with the Beam Sample, 100 psi pressure

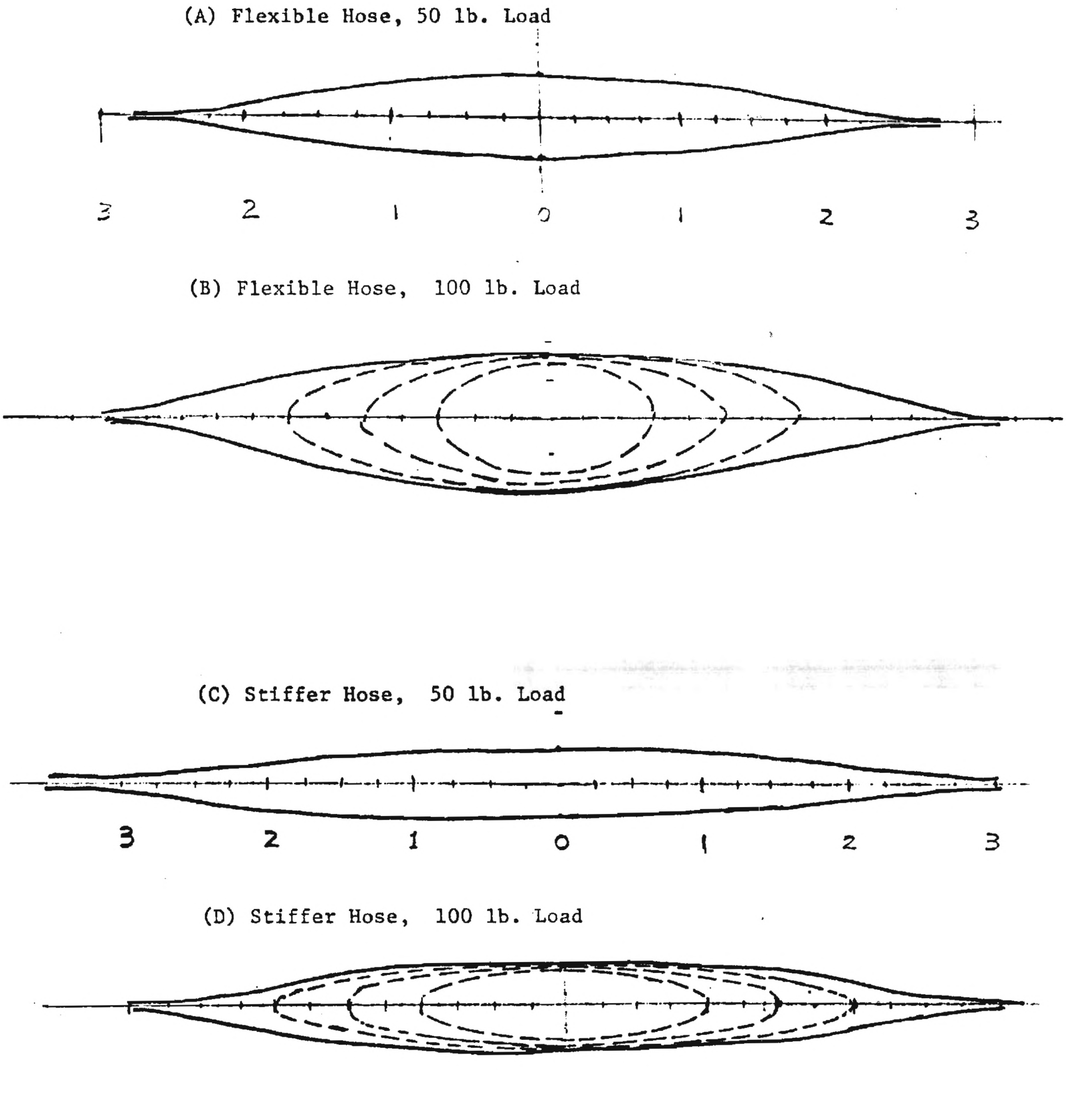


Figure 5 Contact Area of the Rubber Hose with the Beam Sample Under Load, 100 psi pressure

area based on the inflating pressure in the hose, the wheel load and the wheel and hose configurations would be very difficult. However, the shape of the imprints along with the configuration of the aluminum wheel may suggest the approximated pressure distribution contours as shown in Figure 5. It may also suggest that the maximum contact pressure developed for the stiffer hose would be higher than that for the flexible hose. A possible more elongated and high pressure zone developed for the stiffer hose, as shown in Figure 5, would imply that a more severe rutting would be developed on an asphalt beam sample when using the stiffer hose. A series of rutting tests are being conducted by GaDOT Materials Laboratory to validate this effect.

2.4 Temperature Control

In the previous studies [3,4,5] the LWT machine was placed in an airtight temperature control room. This restricts the use of the machine to be in the place where a temperature controlled room is available. The purpose to develop a temperature controlled environmental chamber attached to the machine is to free up this restriction and make the machine more portable. The essential requirements for the environmental chamber are to provide the test sample with a uniform elevated temperature (up to 120^{o}F) during the rutting testing, to provide ease of access to the machine, and to be self-sustaining and easily relocatable.

Based on these requirements, a number of options were investigated. The possibilities of using an off-the-shelf oven and a custom-assembled box to house the LWT machine were investigated. Due to either the problem of fitting the entire LWT in an off-the-shelf chamber or the high cost of acquiring a custom-assembled chamber, it was decided to construct the environmental chamber by ourselves. Again, several versions were investigated. One option was to just enclose a portion of the LWT machine which contains the loaded wheel and the sample and with the other part of the machine including the motor, the reciprocating arms and the weight box not to be enclosed in the temperature controlled chamber. A prototype of this version was constructed and a number of rutting tests were conducted using the prototype environmental chamber to control the temperature of the test sample. It was found that the temperature fluctuation was too much and it was concluded that this version could not meet the temperature tolerance requirements.

The final version of the environmental chamber, shown in Figure 6, was an insulated wood box with inside surfaces attached with heating elements. The entire LWT machine was enclosed in the chamber. A detailed description of the environmental chamber is presented in the remainder of the section.

The environmental chamber consists of a 66-1/4 in. by 23-3/4 in. by 1-1/2 in. thick base and on top of it a shell with the exterior dimensions of 21 in. by 60 in. by 30.5 in. height, see Figure 6 and Figure A-1 in Appendix A. One end of the shell is hinged to the base and the shell can be lifted from the base from the other end. The LWT machine is secured to the base of the chamber with four bolts.

The environmental chamber is insulated with 3/4 in. rigid foam insulation. It is heated with 12 flexible fiberglass heating strips placed evenly along the inside surfaces of the shell, see Figure 6(c). Also providing heat, as well as light, is a 90 watt light bulb placed in the shell of the chamber. The heating strips and the light bulb are all connected to a thermostat, which is placed next to the testing sample. The flexible fiberglass heating strips are connected as shown in Figure 7. The six sets of two heating strips each are wired in parallel, along with the

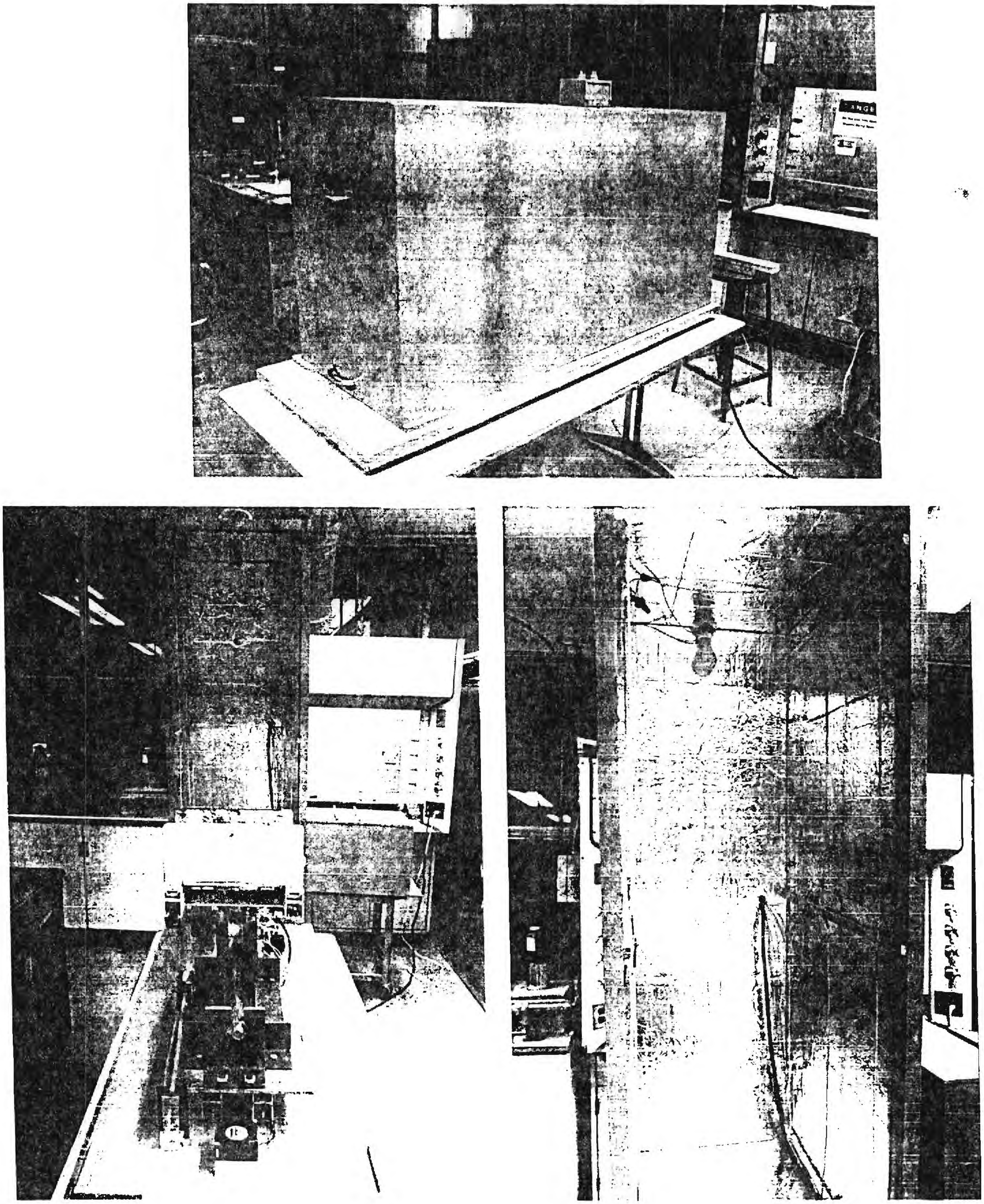


Figure 6. Enviromental Chamber

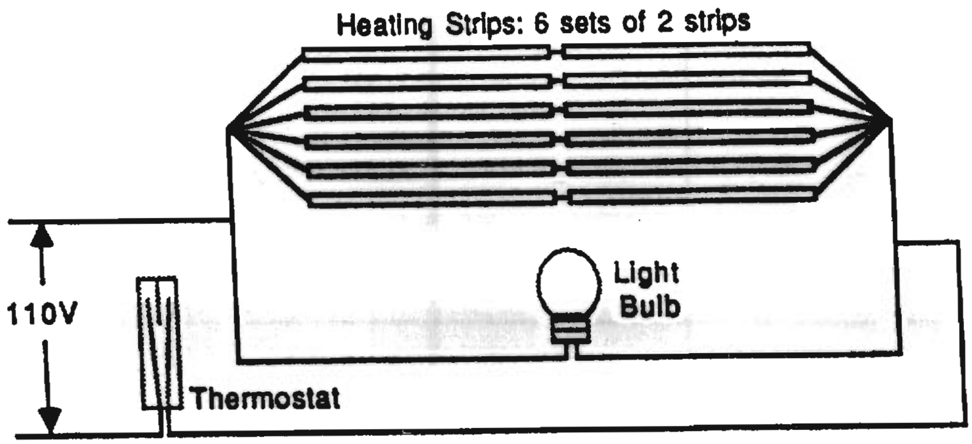


Figure 7. Wiring Diagram for Heating Strips and Light Bulb

light bulb. They are in turn connected in series with the thermostat. This way of wiring enables both the light bulb and the heating strips to turn on when the ambient temperature in the chamber drops below the thermostat temperature setting. The heating will continue until the temperature in the chamber reaches the thermostat setting, then the heating will be turned off.

Since a great deal of heat escapes the chamber when the shell (lid) is raised, the light bulb generally will come on within 5 to 10 seconds after the lid is raised. This helps illuminate the LWT machine and keep the shell heated while it is raised. Figure 8 shows the location of the thermostat (A), the digital thermometer indicating the temperature in the test sample (b). Also shown in Figure 8 are two 20 cfm circulating fans (C,D) which are connected in parallel directly to a 12V DC power supply, and run continuously to keep the temperature in the chamber relatively uniform. Details of temperature control and calibration are presented in Chapter 4.

2.5 Preheating Box

Since the LWT machine is designed to be used in a full-scale laboratory testing program, considerable attention was given to the ease of operation and practicality. Early in the project it was recognized that the time it took to heat the test sample from room temperature to testing temperature was too long. This became necessary to construct a preheating box to precondition the sample to the testing temperature before it is to be transferred to the LWT machine for immediate testing.

Figure 9 shows the preheating box and Figure 10 is the sketch of the cross-section of the box. The box, like the environmental chamber, is made of wood and insulated with 3/4 in. foam. It uses the same type of thermostat, digital thermometer, and similar circulating fans. The heating element has a higher capacity than the heating strips used in the

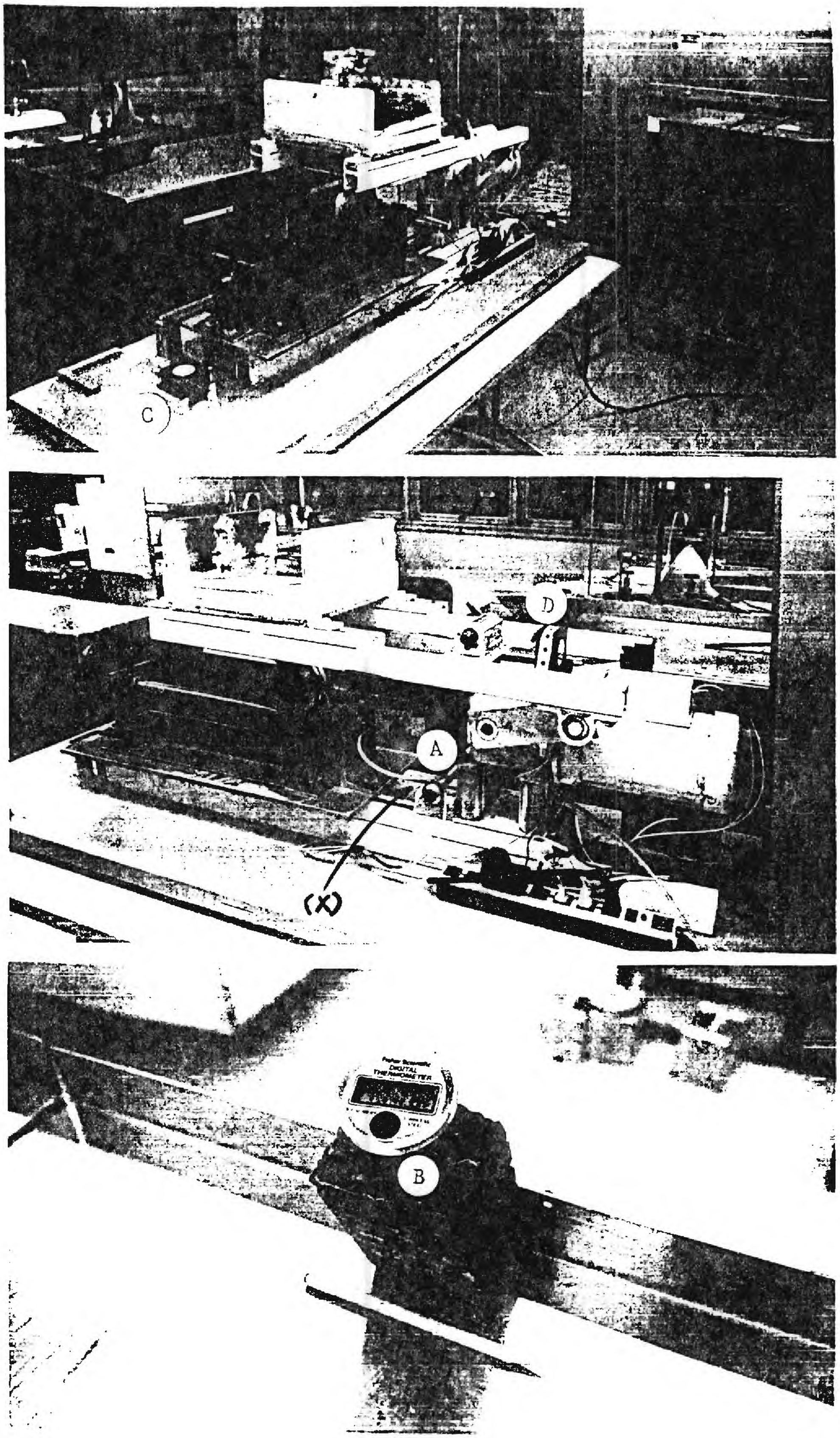


Figure 8. Temperature Control for the Enviromental Chamber

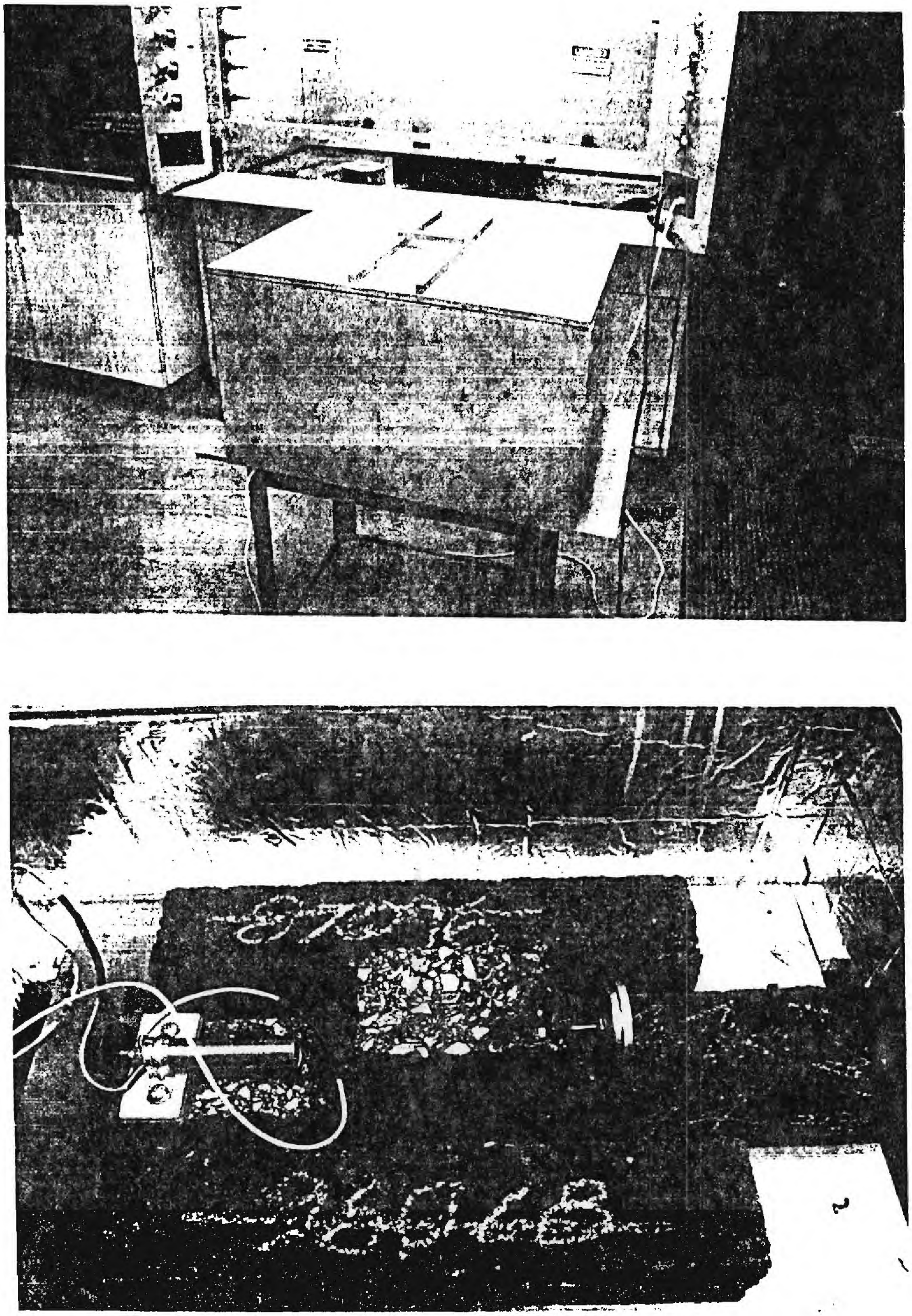
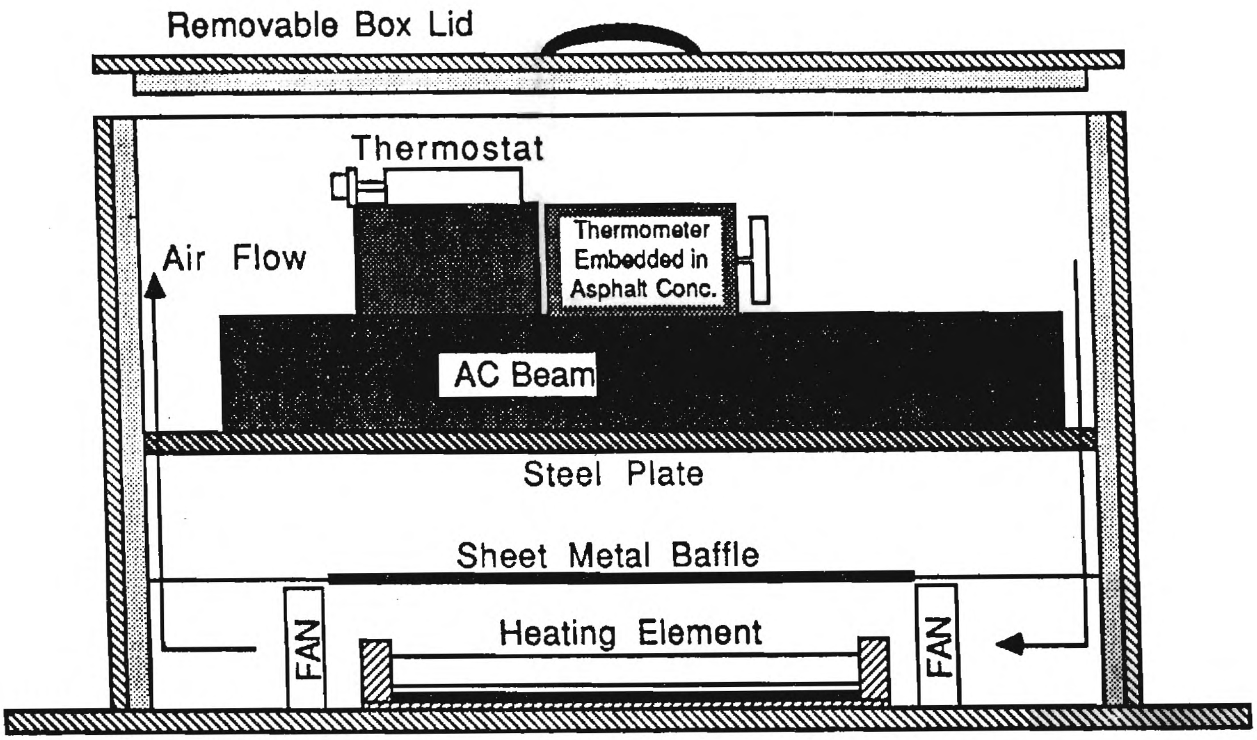


Figure 9. Preheating Box



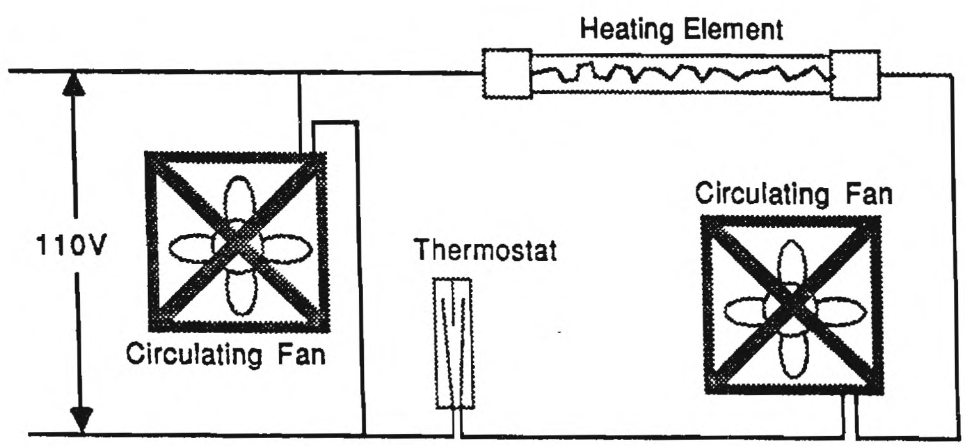


Figure 10. Wiring of the Preheating Box

environmental chamber in order to heat the beam from room temperature to testing temperature relatively quickly. As shown in Figure 9 and 10, the beam samples rest on a 1 in. thick steel plate. The plate is machined smooth to avoid inducing stresses in the beam sample during the preconditioning period. Figure 10 shows that the heating element is placed between two pieces of sheet metal serving as baffles for the heating element. These were necessary to avoid overheating the base of the box, and to more evenly distribute the heat from the heating element. Tests without the top baffle resulted in a "hot spot" on the steel plate directly above the heating element. The temperature in this area was more than 20°F higher than the temperature elsewhere in the plate.

Wiring diagram of the preheating box is shown in Figure 9. Complete plans and specifications for the preheating box are presented in Appendix A, while the calibration of temperature in the beams and that of the thermostat is presented in Chapter 4.

2.6 Other Modifications to the Machine

Besides the modifications described in Sections 2.3 and 2.4 regarding the loading mechanism and the temperature control, additional modifications to the machine include cycle counter, safety measures, and rutting profile measuring device.

Cycle Counter

The LWT machine was previously equipped with a mechanical arm counter to measure the number of cycles of the loaded wheel when the machine is in operation. Enclosing the machine inside the environmental chamber necessitated having a separate remote counter.

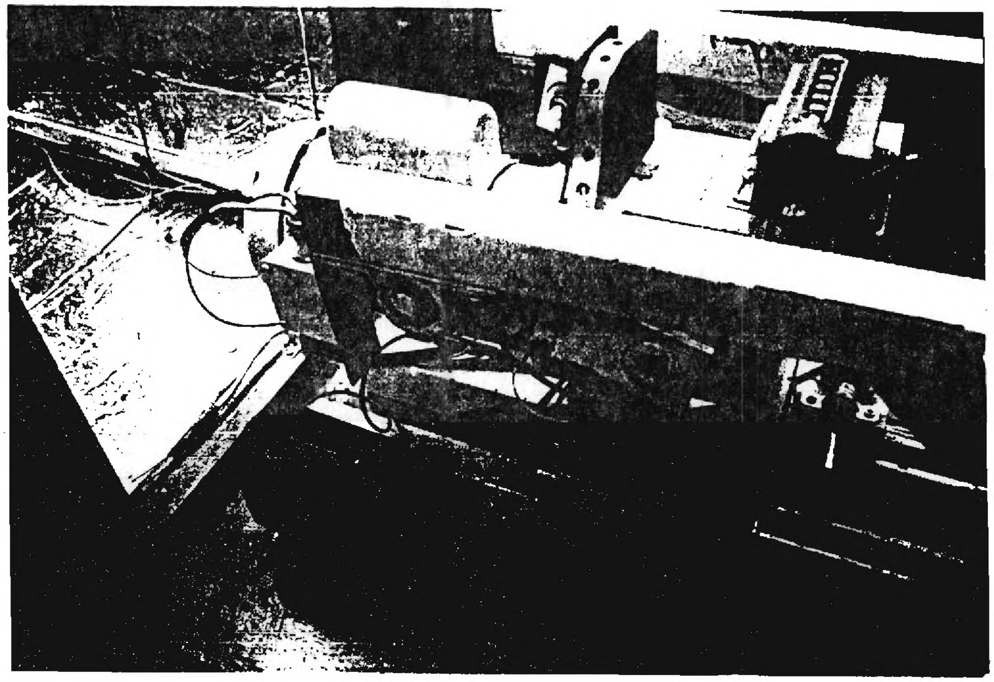
An electric (110V AC) 6-digit counter was placed on top of the environmental chamber lid and wired to an infrared photorelay. The photorelay, see Figure 2(J) and Figure 11, works by bouncing an infrared beam off a reflector. When the beam is broken a 12V pulse is sent through the "output" channel of the photorelay. This goes to a small 5 amp relay, which serves as a switch for 110V AC power connected to the counter. The wiring of the circuit is shown in Figure 11 also.

There is a sensitivity adjustment on the back of the photorelay which adjusts how easily the beam can be broken. A complete description of the photorelay including the sensitivity adjustment is given in Appendix B.

It is important to note that the counter operates in two stages: it moves half a click when the photorelay beam is interrupted, and half a click when the photorelay beam is uninterrupted again. If the LWT machine is stopped in a position where it is blocking the photorelay beam, the counter will be energized until the beam is uninterrupted again. This causes the counter to heat up, and puts excessive wear on the counter motor. As a result, care should be taken not to leave the power to the photorelay and the counter on for a long period of time if the photorelay beam is broken.

Safety Measures

As a safety precaution to prevent the machine to get started when it is in the raised position, as shown in Figure 12, a safety cut-off switch was installed. The wiring diagram is shown in Figure 12. A spring-loaded microswitch (A) similar to that found on the door of an ordinary clothes dryer is installed near the junction of the chamber lid and the base. When the box lid is raised, the switch causes an open circuit and the machine cannot be started. When the lid is closed, the circuit is closed, and the machine can be started by pressing the black "START" button installed on top



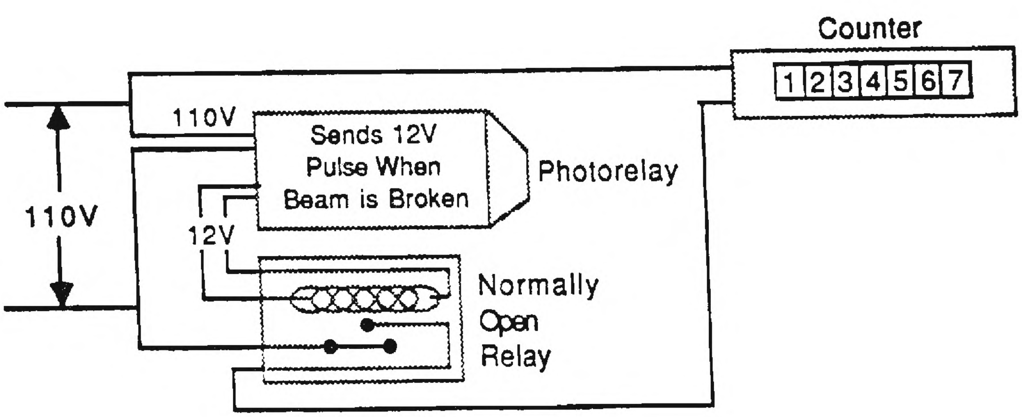


Figure 11. Photoraley for External Counter

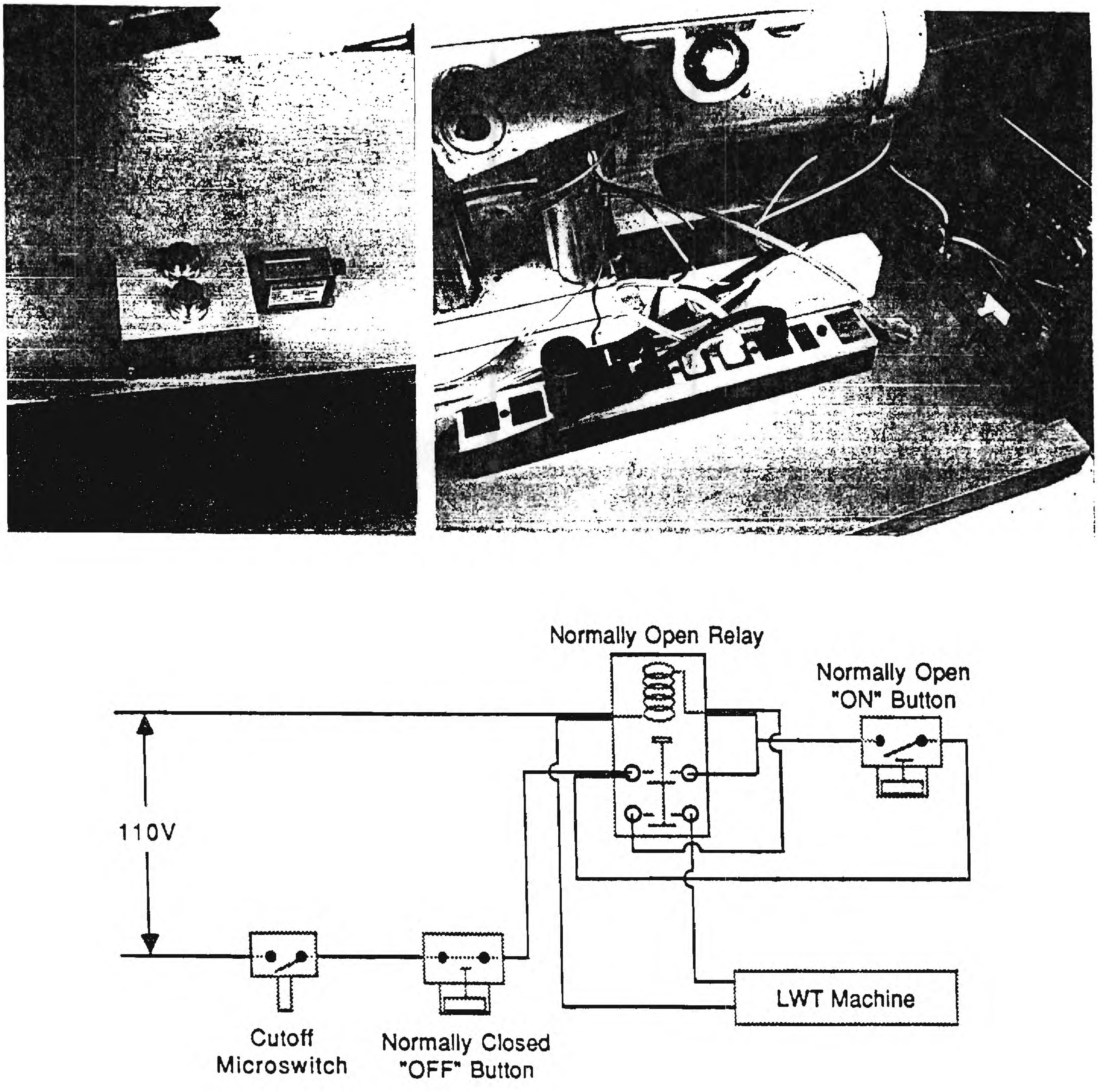


Figure 12. "START", "STOP", and Cutoff Switches

of the chamber lid. The black "START" and red "STOP" buttons are connected to a relay, and are wired with the LWT machine into a "holding circuit". If for any reason this circuit is interrupted (from the microswitch opening, the red "STOP" button being pressed, or power interruption), the LWT machine will shut off and remain off until the black "START" button is pressed again.

Rutting Profile Measuring Device

Figure 13 shows the channel section developed for the measurement of rut profile. The channel section has seven slots marked A-G, having equidistance of 2 in. from each other. Each slot is 3 in. long and 1/4 in. wide. Lines were marked on the top surface of the channel section at 1/4 in. center to center so that cross profile readings could be taken. When the channel section was placed above the beam, slots A and B would be at a distance 1.5 in. from each end of the beam.

A 0.001 in. dial gage was used to measure the rutting on the test specimens. When measuring the surface profile, the channel was placed on top of the sample holding device which served as the common reference plane and the deformation readings were taken by the dial gage by positioning the gage at various positions in the slots.

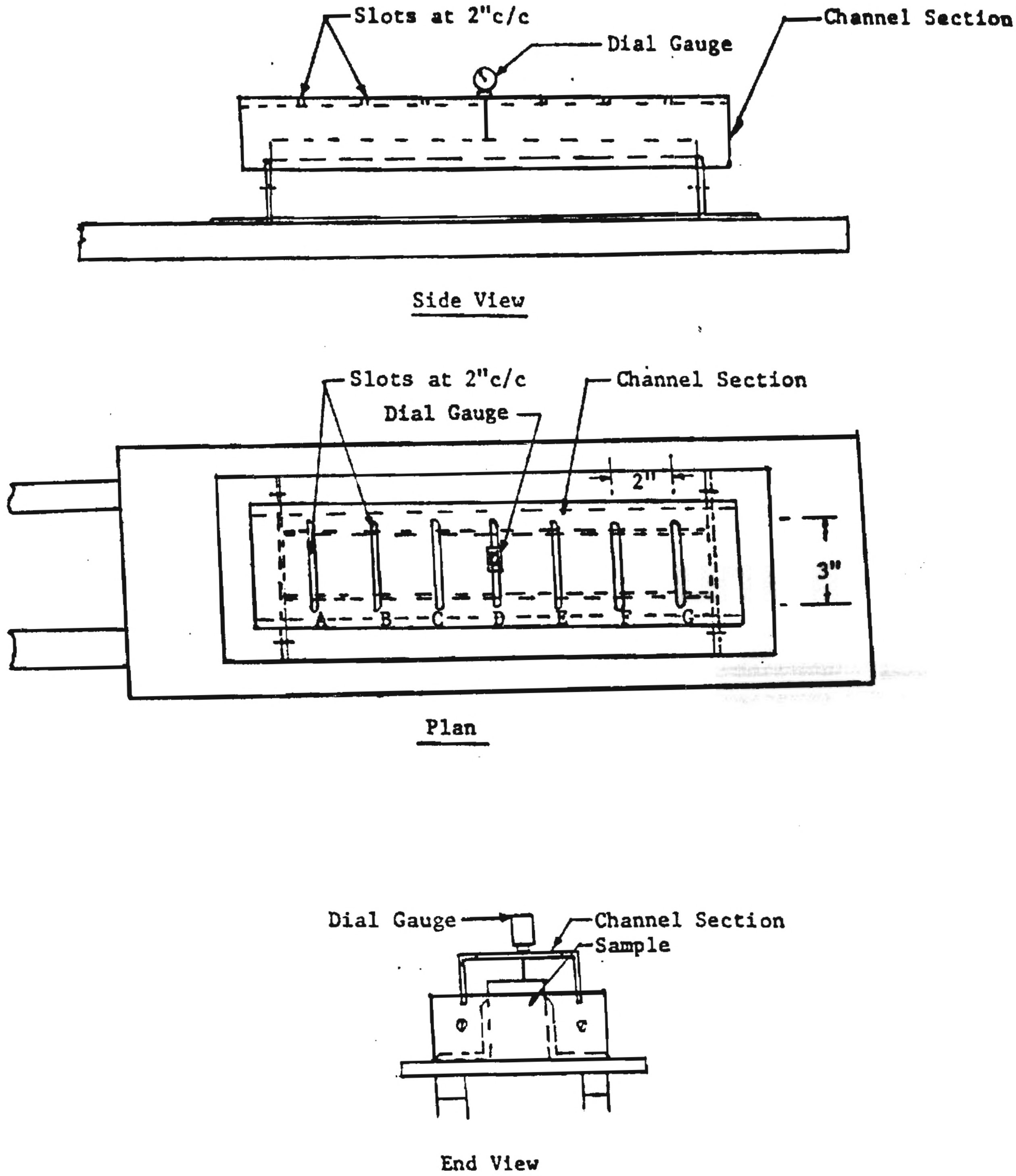


Figure 13. Rutting Profile Measuring Device

CHAPTER 3

DEVELOPMENT OF STATIC COMPACTION SAMPLE PREPARATION PROCEDURES

The 3 in. x 3 in. x 15 in. beam samples used for the LWT rutting test were fabricated using a dynamic kneading compaction machine. The procedure was described in the previous studies [3]. The purpose of this phase of the project was to develop a simplified procedure to fabricate the beam samples by static compression using an universal testing machine. The potential advantages of using a static compression procedure are that the procedure is simpler and takes less time to prepare the sample, and that the equipment is more readily available. Furthermore, most testing laboratories are equipped with larger capacity (200,000 lb. and greater) universal testing machines which makes it possible to fabricate larger asphalt concrete beam samples.

In carrying out this phase of the study several versions of compaction molds were designed and fabricated and different compaction procedures were used to prepare a number of asphalt concrete beam samples. To assess the quality of the beam samples fabricated by different methods, the same asphalt mix (GaDOT "E" mix) using the same aggregate sources and gradation was used. After each beam sample was fabricated, the appearance of the sample and its bulk density was measured. It was then cut into four sections, and the bulk density of each section was measured to evaluate the uniformity of the compaction achieved in the beam sample.

Each stage of development of the beam mold and the beam samples fabricated using the mold were evaluated in terms of ease of handling, problems encountered during sample preparation and quality of the final beam produced. Modifications and improvements were made and were incorporated into the next stage of development.

3.1 Development of Sample Molds and Sample Fabrication Procedures

The first attempt used a mold made of 1/2 in. steel plate, with dimensions of 3 in. (wide) x 15 in. (long) x 5 in. (high) and a fixed bottom plate. The 5 pieces of the mold (2 side pieces, 2 end pieces and one bottom piece) were assembled together with hex screws. To remove the finished asphalt concrete sample, the mold had to be disassembled. This idea was abandoned after only one attempt because of the extreme difficulty in removing the sample. The mold was difficult to disassemble, even more difficult to reassemble. Also the mold assemblage was too heavy to handle.

The next attempt used an existing 18 in. long mold, normally used to fabricate beams in a kneading compaction machine. This mold was also made of 1/2 in. steel plate, and had dimensions of 3 in. (wide) x 18 in. (long) x 4 in. (high) and a removable bottom plate. A 3 in. spacer was placed in the end of the mold to provide a finished beam of 15 in. long. The removable bottom plate allowed the beam to be extruded using the same universal testing machine that compacted it. This extrusion procedure proved much easier.

Attention was focused on bulging in the walls of the mold under compression. Initial attempts to control the bulging used a steel "collar", consisting of two pieces of 2 in. x 2 in. x 20 in. steel connected by bolts. Although effective, this collar proved unwieldy, and was deemed unnecessary for a 15 in. mold.

The final mold was 15 in. long, 3 in. wide, and 6 in. high. It was made of 3/4in. steel, and had a removable bottom plate. Bulging in the sides of the mold was less than with the unreinforced 18 in. mold, which allowed the steel collar approach to be abandoned. Figures 14 shows

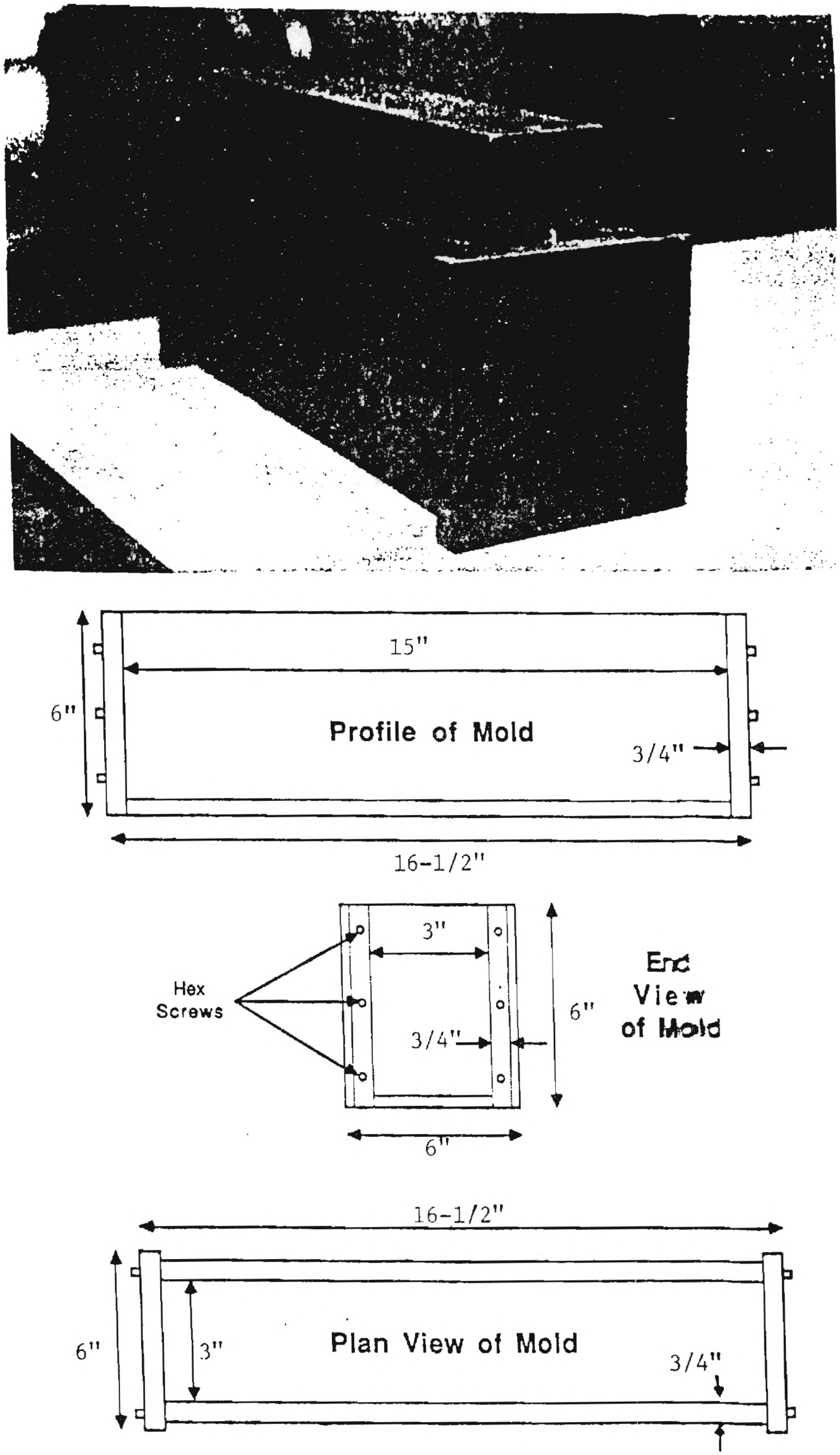


Figure 14. Static Compaction Beam Mold

the finished mold and other parts needed for fabrication of the samples. This final version of the mold was relatively easy to use. It did not require disassembling the bottom plate, and did not have the extra weight of the massive steel collar. The mold assemblage is light enough to be handled by one person.

3.2 Results

Excluding several preliminary trial runs, seven beam samples were fabricated using different static compression methods. Information on the mix design and the results of the sample fabricated for all seven samples are presented in Appendix C. The first beam was made using a mold without a removable bottom plate, and next three were made with an 18 in. long mold with a 3 in. spacer inserted, and the final three beams were made with the final 15 in. mold. Among all the seven samples, the mixes were all prepared at a mixing temperature of about 280°F ± 3°F. The compaction temperature varied significantly from 260°F to 230°F. The significant drop in temperature from mixing to compaction was primarily due to the time it took to transfer the loose asphalt mix from the asphalt laboratory to the structural laboratory where the universal testing machine was located. Because of the drop in temperature, the maximum compression load applied to the asphalt mix in the mold to achieve the desired bulk density was at about 80,000 lbs. ± 5000 lbs. (1700 ± 100 psi). The procedure used for preparing the last six beam samples were substantially identical to the procedure described in the next section. The results of the bulk densities of the seven beam samples prepared by the three different methods are shown in Table 1. Generally speaking, the results are quite consistent.

After the seventh beam sample was fabricated, the progress of this phase of the study was evaluated. Our conclusions were that the last

Table 1. Unit Weight of Static Compaction Samples

Total refers to the unit Wt. of entire beam
A, B, C, and D refer to unit wt. of each
segment of the cut up beam.

Beam Number	Unit Weight of Beams (pcf)				
	Total	A	B	C	D
1	141.4	140.2	138.3	141.8	140.0
2	139.4	140.3	137.8	140.8	138.3
3	138.7	136.9	136.9	139.6	136.7
4	138.7	137.1	139.0	137.5	140.5
5	137.9	137.8	137.8	137.2	137.8
6	137.8	-------	-------	-------	-------
7	137.3	-------	-------	-------	-------

version of the beam mold was quite workable and that the static compression procedure used for making the beam could achieve the desirable bulk density. Even though the sample preparation procedure could be further refined to achieve even better and controllable results, we felt at that time that because of the obstacles we were facing in our laboratory, it would be better to let the GaDOT Materials Laboratory to fine-tune the procedure. The main obstacle we were facing was the distance between the asphalt laboratory where the asphalt mix was batched, and the structural laboratory where the beam sample was fabricated. The long traveling time between the two laboratories caused significant and uncontrollable cooling of the mix and the mold. We believed that if the mix temperature could be maintained at 280^{o}F, the static compressive load required to achieve the desired bulk density could be significantly reduced. The static compression molds were turned over to GaDOT Materials Laboratory for further evaluation.

Since then, GaDOT Materials Laboratory has been able to make substantial refinement in fabrication of the asphalt beam samples. By being able to maintain the mix temperature during batching and compaction, it has been able to fabricate asphalt beam samples at a substantially lower compressive load of about 58,000 lb. (equivalent to 1300 psi). This was accomplished by slightly modifying the compression procedure as described in the next section.

3.3 Suggested Beam Sample Preparation Procedure Using Static Compression

<u>Apparatus</u>

Universal Testing Machine capable of exerting a load of at least 100,000 pounds.

Mold made of 1/2 in. steel plate, and assembled to interior dimensions of 3 in. width and 15 in. length. The end plates can be secured to the side plates using 6 hex screws, or by adequate welding. The mold should be at least 5 in. deep, and should have a removable bottom plate (3 in. x 15 in.) that fits securely in the mold. The mold should also have an extrusion cap to aid in removing the beam sample from the mold.

Compression Foot: a steel "I-beam" slightly under 3 in. wide. An S-4 x 9.5 (AISC, 8th Edition) section with a 3 in. x 15 in. plate welded to one of its flanges is suitable.

Ovens large enough to heat the mold and compression foot, as well as the aggregate and any miscellaneous equipment that needs to be heated.

Asphalt Mixing Equipment: bowls, spoons, spatulas, pans, scales, gloves, thermometers, paper liners to reduce sticking between mold and asphalt.

Procedure

Batch two lifts of aggregate[1] at the prescribed gradation. Total weight of aggregate should be determined, considering the targeted final unit weight of the beam and the sample size.

Heat the aggregate and the asphalt cement to the appropriate temperature, using the same temperature for making Marshall samples.

Preheat mold, base plate, and compression foot to 350°F. Preheat raw materials and all equipment necessary to mix the asphalt concrete. Appropriate temperature will be dictated by the mix design of the asphalt concrete.

Remove the mold from the oven and center it under the head of the universal testing machine. Place the base plate and a paper liner in the bottom of the mold.

Spoon the first lift of asphalt concrete into the mold. Use a spatula to vigorously tamp the mix in the mold. Monitor the temperature of the mix, and make sure it does not drop below 260°F.

Follow the same procedure for the second lift (if two lifts are used).

Place a paper liner on top of the asphalt concrete and place the compression foot on top of the liner.

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1. One lift may be used if the laboratory procedure is efficient enough to maintain adequate temperature during mixing.

Load the compression foot as follows for a GaDOT "E" Mix:

Maximum Load	80,000 lbs.
Loading Rate:	
Reach 60,000 lbs (75% of max.) at:	1 min
Reach 80,000 lbs (max.) at:	2 min
Duration at 80,000 lbs:	5 min

Use a dial indicator to monitor the movement of the loading head. Final sample should be 3 in. high, ± 0.05 in.

Unload the mold, remove the compression foot and remove top and bottom pieces of filter paper, and place the mold aside to allow it to cool.

GaDOT Materials Laboratory has since modified the procedure as follows: Apply a maximum load of 58,000 lb. to the sample. As soon as the applied load reaches the 58,000 lbs., release the load immediately. Then reload to 58,000 lb. and release once more. Then reapply the load to 58,000 lb. and hold the load for about 5 minutes. This procedure, while substantially lowering the compression load, can achieve the same bulk density of the beam sample and can also minimize the bulging of the beam mold side walls.

When the mold is cool to the touch, the beam may be extruded. Place the compression foot back on top of the beam, and flip the entire mold so that the beam is resting on the compression foot. Place the extrusion cap on top of the mold, and gradually apply a compressive load in the universal testing machine to extrude the sample, as shown in Figure 15.

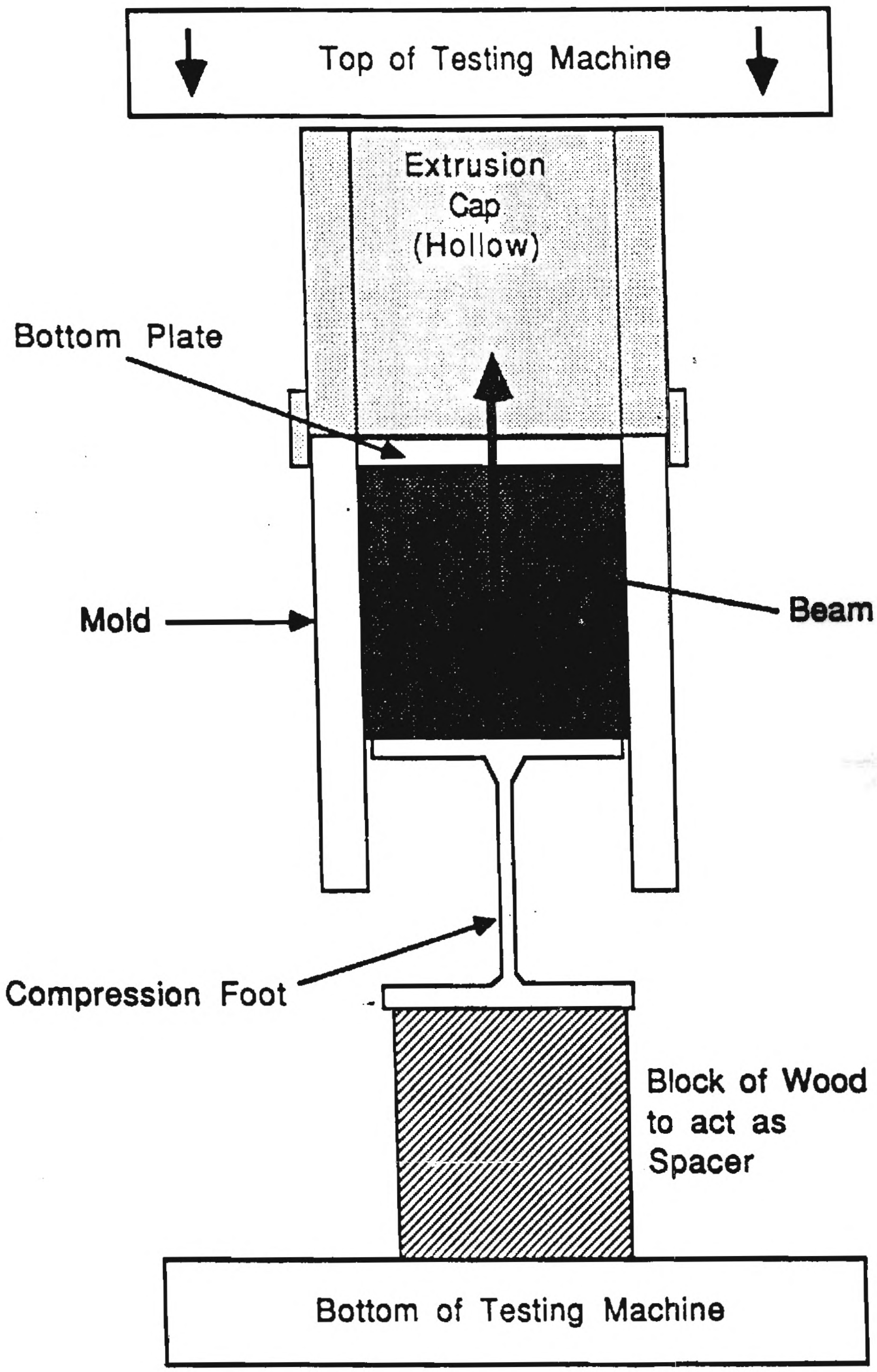

Figure 15. Method of Extruding Beam Sample From Mold

CHAPTER 4

DEVELOPMENT OF RUTTING TEST PROCEDURE

Tentative procedures for using the LWT machine to determine rutting resistance of asphalt concrete beam samples have been developed in the previous studies [3,4,5]. With the development of the environmental chamber and other modifications and improvements to the LWT machine described in Chapter 2, the testing procedures have been modified accordingly. The following describes various modifications developed in the course of this study.

4.1 Calibration of Temperature Control

Since the goal of the environmental chamber and the preheating box was to provide a constant temperature at a certain preset level, this would require that the thermostats in the environmental chamber and the preheating box be calibrated against the temperature in the beam samples so that the setting on the thermostats could be adjusted to keep the temperature in the beam samples to a certain prescribed level. The temperature in the beam sample was monitored indirectly by monitoring the interior temperature of an asphalt concrete block (temperature monitoring block) placed adjacent to the beam samples to be monitored. The temperature monitoring block is a 3 in. x 3 in. x 4 in. asphalt concrete block. A 1/4 in. hole by 3 in. deep was drilled at the center of the block. The hole was then partially filled with hot asphalt cement. While the asphalt cement was still warm, the stem of a digital metallic thermometer was pressed into the center of the hole. When the asphalt cement in the hole cooled to room temperature, the hole and exposed portion of the stem of the thermometer were coated with epoxy to keep the asphalt cement from creeping out of the hole. Two temperature monitoring blocks, see Figure 8 and 9, were constructed.

Calibration was conducted between the thermostat setting and the interior beam temperature. Figure 16 shows schematically the logic of controlling the temperature in a beam sample (temperature monitoring block) by the thermostat. As the air temperature sensed by the thermostat is lower than the thermostat setting, the thermostat turns on the heating elements and the fans to heat up the air and force the hot air to circulate in the box and thus gradually cause the temperature in the beam sample to rise. When the air temperature exceeds the thermostat setting, the thermostat turns off the heating elements and allow the hot air in the box to continuously heat the beam sample. At the same time the hot air in the box is gradually cooling down. The heating cycle restarts when the air temperature in the box dropped below the thermostat setting. Calibration for the thermostats to be placed in the environmental chamber and in the preheating box was conducted separately. The results of the calibration curves are shown in Figure 17.

Temperature Control in Preheating Box

Since the preheating box must heat asphalt concrete beams from a room temperature of around 70°F to a testing temperature as high as 125°F, some uniformity was sacrificed for speed of heating. As shown in Figure 18, three beams at a room temperature of 72°F placed in the preheating box (the box already heated to the preset temperature) take approximately 4 hours to reach that preset temperature. Because of the large amount of heat emitted by the heating element in the preheating box, the temperature in the beam being heated can be somewhat uneven, and appears to significantly depend on the location of the beam placed in the preheating box. As shown in Figure

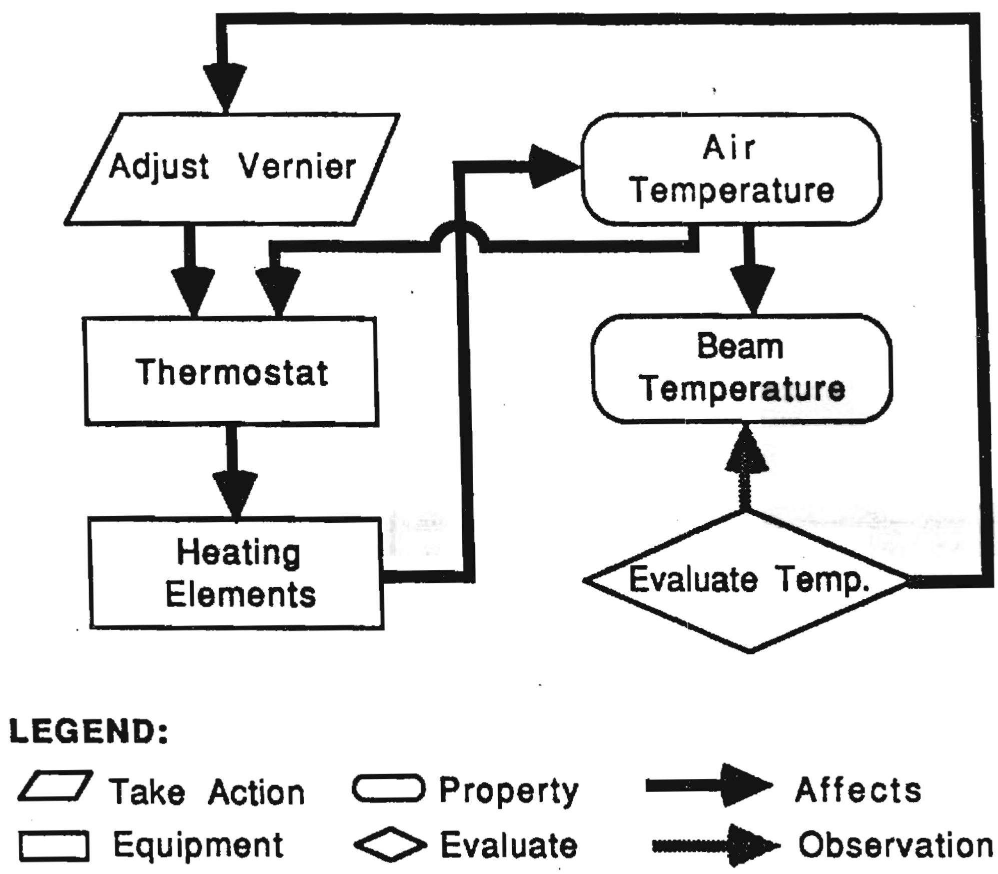

Figure 16. Effect of the Thermostat Settings on Interior Beam Temperature

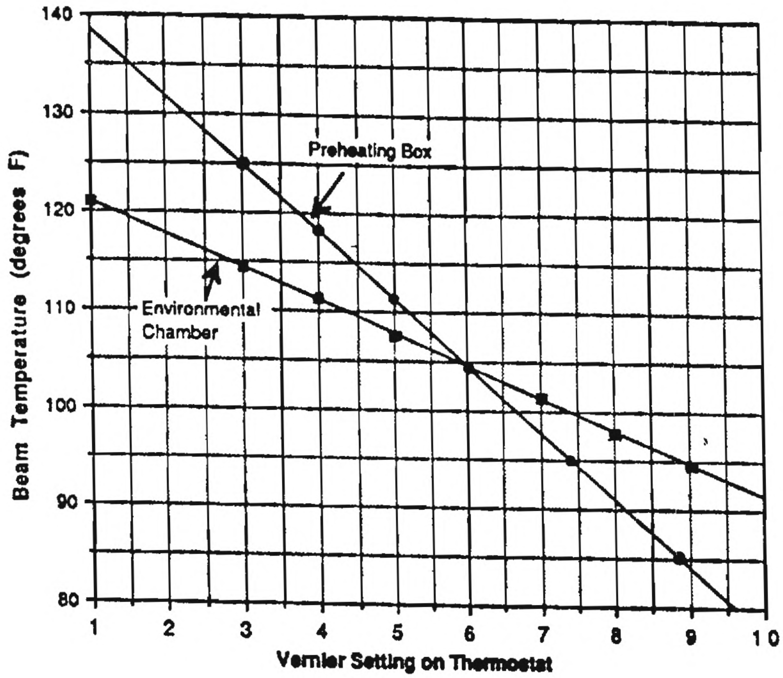

Figure 17. Calibration Curves Between the Thermostat Steeings and Beam Temperature

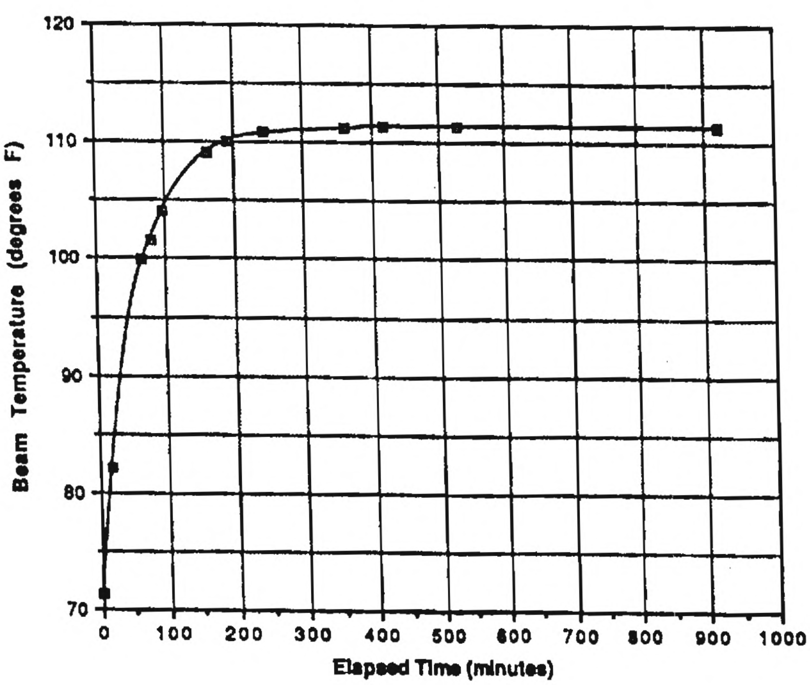

Figure 18. Asphalt Beam Temperature VS Time in the Preheating Box

10, hot air is forced up from under one end of the steel plate and is drawn down from the other end. When the heating element is on, the forced air is significantly hotter than the beams. This means that the placement of the beams and the placement of the thermostat are critical to uniform performance. Figure 19 shows the recommended arrangement for the beam samples, the thermostat, and the temperature monitoring block in the preheating box. Three beam samples is the maximum number that should be heated in the box at any time.

Temperature Control in Environmental Chamber

The temperature control mechanism described in this section is working quite well in controlling the temperature in the beam sample. Because of the sensitivity of the thermostat and the arrangement of the thermostat in the chamber, it was found that there was an average of above 7°F fluctuation in air temperature during normal operation of the thermostat.

4.2 Testing Temperature

In the three previous studies using LWT machine to evaluate rutting behavior of asphalt mixes, two temperatures 95°F [3,4] and 105°F [5] were used. An earlier study [8] suggested that 95°F temperature level was critical for asphalt pavement to develop rutting under truck traffic. Therefore 95°F was chosen in the first two of the previous studies conducted by the author. In the second study [4], it was found that in many instances the rutting on the beam samples was not sufficiently developed even up to 10,000 cycles of load repetitions. In the subsequent study [5] the temperature was raised to 105°F. At that test temperature and at 100 lb. load and 100 psi pressure, rutting on the beam samples was found to be in the range of 0.15 to 0.25 in. at 8000 cycles of load repetitions. Results

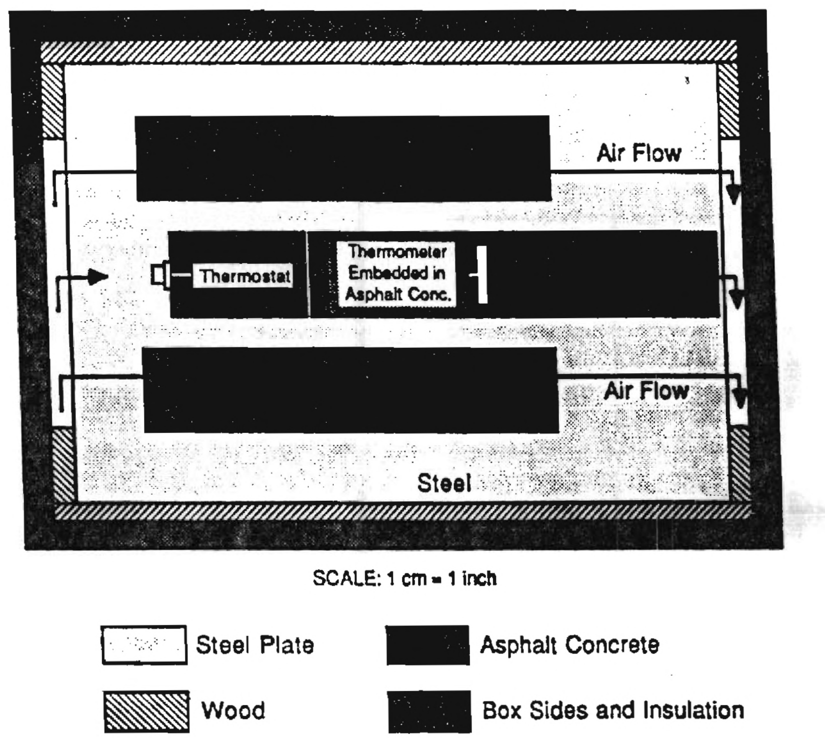

Figure 19. Recommended Placement of Asphalt Beams in Preheating Box

of the rutting tests have shown that 0.20 in. to 0.22 in. of rutting on the beam sample, measured in the middle portion of the beam sample, was about the maximum the rutting should be allowed to develop. At this point excessive rutting would occur near the ends of the test sample and the material there was starting to crumble.

In this study the effect of using different test temperature was originally contemplated. Due to time limitations, only a limited scope of the study was carried out. Two mixes were chosen for this evaluation. These two mixes were among the 16 mixes used in the previous study [5] and were identified as DBA and DX mixes. The gradation and asphalt mix characteristics of these two mixes are presented in Table 2. Two rutting tests were run at $105^{o}F$ and one rutting test was run at $115^{o}F$ for each mix. The results are shown graphically on Figure 20. The results show that at $115^{o}F$ test temperature, rut depth was developed much more rapidly than at $105^{o}F$. The characteristics of rut depth vs. number of repetitions for these two mixes at $105^{o}F$ and $115^{o}F$ test temperatures are significantly different. However, in view of the potential variability of the rutting test results experienced in the previous studies, it will not be possible to draw any definitive conclusions from this limited test results.

4.3 Contact Pressure and Wheel Load Magnitude

In the previous study [3] the effect of the contact pressure (75 psi, and 100 psi) and the magnitude of wheel load (50 lbs., 75 lbs., and 100 lbs.) were investigated. Results of the rutting tests on the four types of asphalt mixes using different combinations of the contact pressure and the wheel load showed that at the highest contact pressure and the wheel load (100 psi and 100 lbs.) the rutting characteristics of the four asphalt mixes were much more distinguishable than that at the lower contact pressure and

Table 2. Gradations and Asphalt Mix Characteristics

Aggregate Source: Dalton, Georgia

Reference [5]

COMBINATION	BA	B	CB	X	XX
SOURCE	Vulcan @ Dalton	Vulcan @ Dalton	Vulcan @ Dalton	Vulcan @ Dalton	Vulcan @ Dalton
BLEND	28% - 5 16% - 7 40% - 012 15% - Min 1% - Lime	36% - 6 19% - 89 33% - Mio 11% - Min 1% - Lime	36% - 6 12% - 89 36% - 012 15% - Min 1% - Lime	40% - 7 30% - 89 12% - Mio 17% - Min 1% - Lime	40% - 7 19% - 89 20% - Mio 20% - Min 1% - Lime
GRADATION: 1½	100				
1	98	100	100		
3/4	82	98	98	100	100
1/2	73	77	77	97	97
3/8	64	68	67	80	80
4	43	52	44	41	48
8	34	38	33	30	38
16	28	27	25	24	30
30	22	19	20	20	24
50	13	12	12	11	13
100	8	7	6	6	7
200	5	5	5	4	5
DESIGN DATA: OPT. A.C.	4.5	4.7	4.8	5.2	5.1
THEO. GRAV.	2.629	2.568	2.604	2.577	2.602
ACTUAL GRAV.	2.508	4.452	2.487	2.460	2.490
% VOIDS	4.6	4.5	4.5	4.5	4.3
DENSITY	156.5	153.0	155.2	153.5	155.4
VMA	15.5	15.6	16.1	16.3	16.6
% VOIDS FILLED	70.3	71.1	71.5	72.4	74.1
STABILITY	2140	2130	1880	1810	2120
FLOW	11.6	10.0	10.7	12.2	11.0
EFF. GRAV.	2.835	2.770	2.820	2.806	2.832
T/S (% VOIDS)	6.2	5.7	7.0	6.6	6.3
T/S (CONTROL)	101.2	118.9	95.2	90.3	76.2
T/S (CONDITIONED)	85.3	97.6	76.8	72.1	77.7
% RETAINED	84.3	82.1	80.7	79.8	102.0
MODIFIED T/S	45.8	41.2	39.2	36.9	37.0
STIFFNESS	11,475	11,019	10,068	8,311	9,287
RUT DEPTH (8000 CYCLES)	.182	.229	.208	.218	.285

the lower applied wheel load. In this study several preliminary tests were conducted in an effort to assess the possibility of increasing the magnitude of the wheel load beyond 100 lbs. The main concerns of using higher wheel load were the stability of the tracking mechanism and the possibility of causing excessive wear on the machine. It was observed that the tracking mechanism remained quite stable for the applied wheel load up to 130 lbs. However at this wheel load, excessive rutting and deformation was observed near the ends of the beam specimen. It was also a concern that imposing a heavier load on the testing machine and with the entire machine enclosed in the environmental chamber might possibly cause the motor to overheat. Because of these reasons, it was decided that the maximum wheel load should remain at 100 lbs. in order to prolong the life of the testing machine.

4.4 Suggested Rutting Test Procedure

The test procedure described in the following steps represents our suggestions for using the modified LWT machine for conducting the rutting test.

1. Place the beam samples (up to 3) in the preheating box and allow the samples to be heated to the prescribed temperature for at least 6 hours.

2. If the testing machine has not been heated to the testing temperature already, turn on the heat in the environmental chamber and close the chamber lid to allow the machine in the chamber to reach to the testing temperature (it will take about 2 hours).

3. Activate the photorelay and electric counter and pressurize the hose to the prescribed pressure.

4. Remove a test sample from the preheating box and place it in the sample holding device, tighten the steel bracket plates, and clamp down the rubber hose.

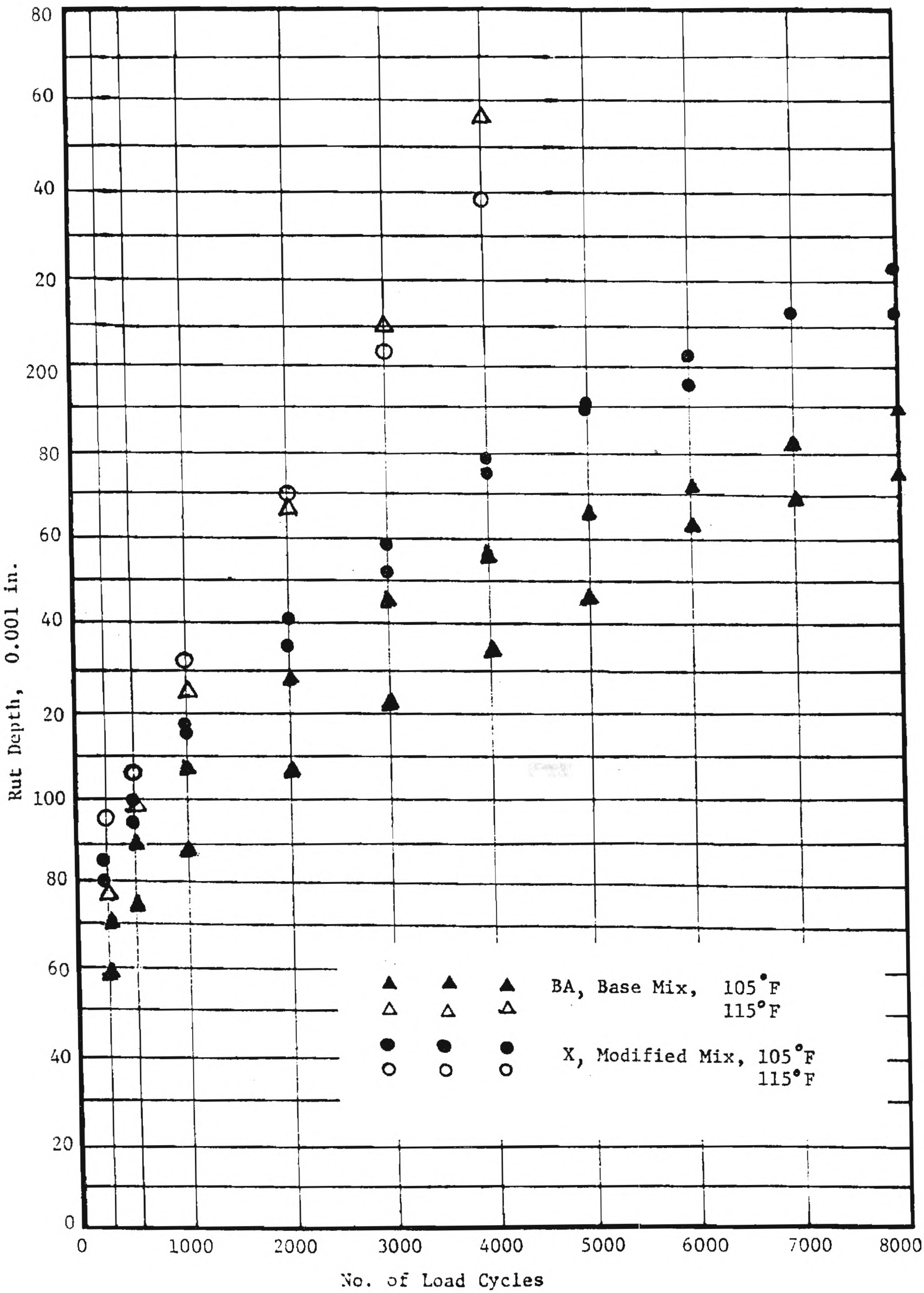

Figure 20. Rut Depth VS. Number of Load Cycles at 105°F and 115 °F

5. Lower the wheel onto the rubber hose and place weights in the weight holding box.

6. Close the environmental chamber lid and press the "START" button on top of the chamber lid. The LWT machine will begin running.

7. Monitor the number of cycles of the machine from the counter on top of the lid. When the machine reaches the desired number of cycles, lift up the cover and the machine will automatically stop running.

8. Quickly remove the weights, prop the loading wheel up and remove the rubber hose.

9. Measure the rutting profile by using the measuring device described in Section 2.6. Note the number of cycles on the internal counter. This should compare reasonably close with the external counter. If there is a discrepancy, take the reading from the internal counter.

10. If it is necessary to continue the test, put the rubber hose back on top of the sample, lower the wheel and put the weights back in the weight holding box. Lower the chamber cover and press the "START" switch on top of the cover.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

A loaded wheel testing machine which had been used in the previous studies to evaluate the rutting characteristics of asphalt mixes was undergone several modifications and improvements. The improvements and modifications made to the LWT machine include the development of an environmental chamber for maintaining a constant prescribed temperature for the test sample during the rutting test, and the development of a preheating box for preconditioning the test sample to the prescribed temperature. Other modifications and improvements for the control and the operation of the machine were also made. Another major effort was to develop a beam sample preparation procedure using a static compression machine.

Conclusions

Specific conclusions concerning the modifications and improvements of the LWT machine and the testing procedures are summarized in the following:

1. A novel method of generating a moving wheel load on asphalt beam sample using a loaded wheel riding on a pressurized rubber hose (linear tube assemblage) has been shown to be a practical alternative to the conventional method of directly applying a loaded moving wheel on the sample. By controlling the stiffness of the rubber hose and the pressure in the hose as well as the magnitude of the weights applied on the wheel, the contact pressure and the contact area between the rubber hose and the beam sample surface can be kept constant. It was found that the excessive rutting occurred at both ends of the asphalt concrete beam sample and the excessive nonuniform rutting observed along the wheel path which were encountered by

applying the loaded moving wheel directly on the beam sample could be substantially reduced by using the linear tube loading method.

2. It was found that the stiffness of the rubber hose could affect the rutting characteristics of the sample. Therefore the stiffness of the rubber hose should be standardized.

3. An environmental chamber for providing a constant elevated temperature during the rutting test was designed and constructed. The chamber consists of a base of which the LWT machine is attached and a cover which is hinged on one end to the base. The entire LWT machine is enclosed in the environmental chamber and the temperature of the test sample in the chamber can be controlled by a thermostat to within ± 1°F.

4. A preheating box for preconditioning the beam samples to the prescribed elevated temperature was designed and constructed. The beam samples in the box can be slowly brought from room temperature to the prescribed elevated temperature of up to 125°F for about 4 hours. The temperature of the beam samples in the preheating box is controlled by a thermostat.

5. Calibration of the thermostats with the temperature of the test samples in the preheating box and the environmental chamber were made. With the thermostats placed at certain prescribed locations in the environmental chamber and the preheating box, the temperature in the test samples can be controlled to within ± 1°F range.

6. An asphalt concrete beam sample preparation method by static compression using an universal testing machine was developed. The beam samples fabricated by this method could achieve the desirable bulk density. The method has shown to be practical and has several advantages over the kneading compaction method which was used in the previous studies.

7. A rutting test procedure using the LWT machine was developed in this study.

Recommendations

The following recommendations were developed from this study.

1. The beam sample preparation procedure using the static compression method proposed in this study could be further improved. The magnitude of the maximum compressive load and the ways the maximum loading is to be applied and maintained during the sample preparation process in order to achieve the desirable bulk density will depend on the temperature of the mix maintained during compaction as well as possibly the characteristics of the mix. It is recommended that mixing and compaction of the asphalt mix should be done at close proximity, and that the temperature during compaction should be kept relatively stable. Under these conditions, compaction procedures in terms of maximum compressive load, the rate of loading and the duration of holding the maximum load before releasing should be experimented to obtain an optimum procedure for achieving uniform prescribed bulk density for the beam samples.

2. One of the main concerns of the rutting test using the LWT machine was that the 3 in. x 3 in. cross section sample size used could be too small. This concern cannot be overlooked for coarse mixes such as the GaDOT B mix. In all the previous studies, this particular sample size was chosen due to the limitation of the capacity of the kneading compaction machine available in the laboratory. With the static compression method developed in this study, a 3 in. x 3 in. x 15 in. beam sample can be compacted at a maximum load of under 60,000 lbs. Since most of the universal testing machines have the capacity in excess of 100,000 lbs., it is possible to prepare a larger cross section beam sample if needed. It is recommended

that the procedure for fabricating beam samples of other than 3 in. x 3 in. x 15 in. size should be explored.

3. The effects of using higher testing temperature than the 105°F recommended in this study could be further explored. Using higher testing temperature could shorten the number of cycles needed to evaluate the rutting potential of asphalt mixes. On the other hand, it could also possibly cause the rutting characteristics of different asphalt mixes to be less distinguishable.

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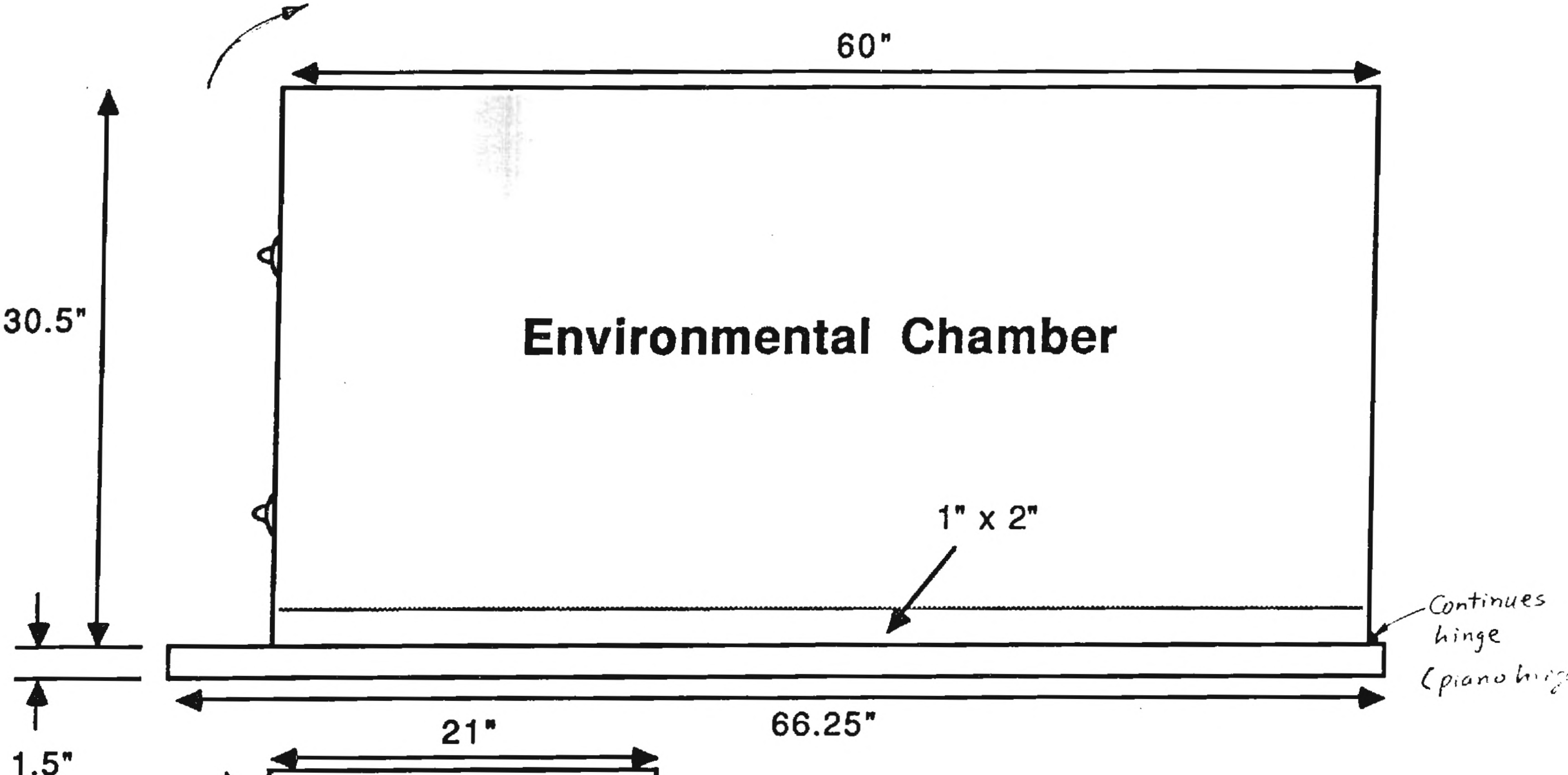
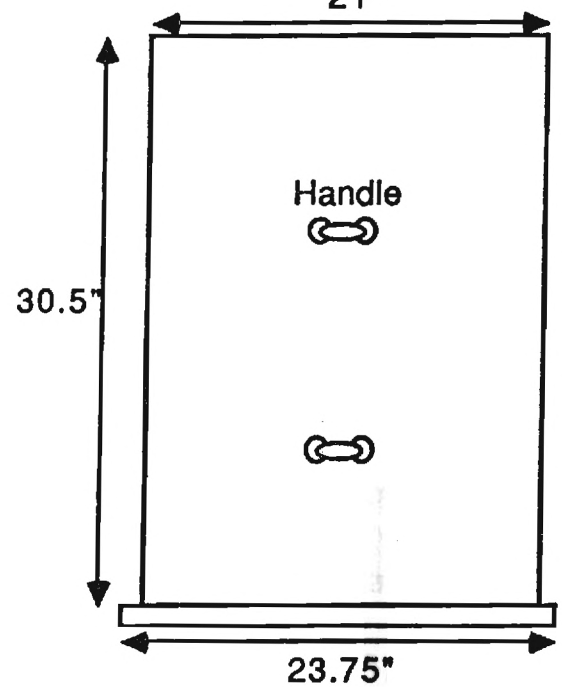
APPENDIX A

Plans for Enviromental Chamber

and Preheating Box

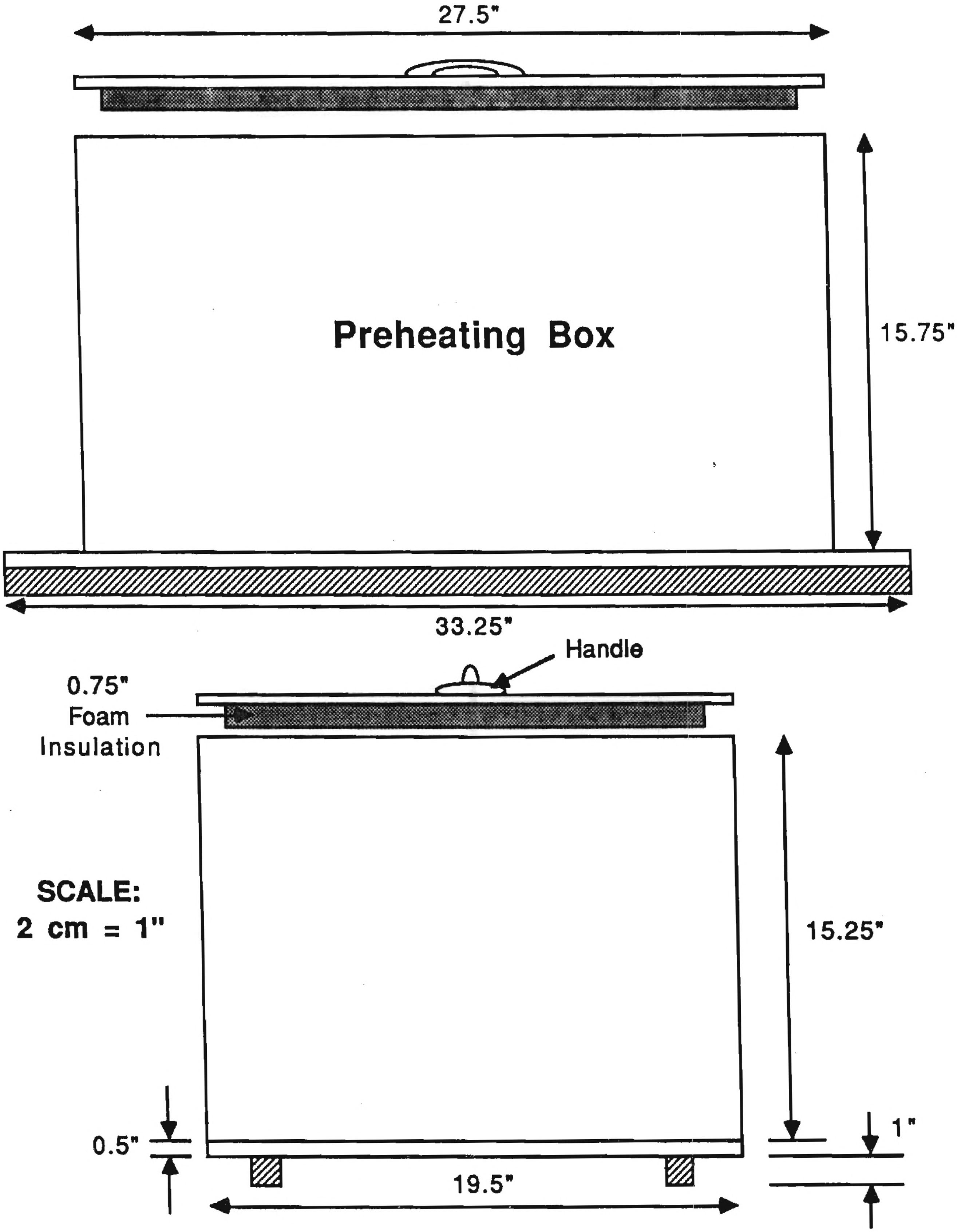


SCALE:
2 cm = 1"



The base consists of a base made of (2) pieces of 0.75" plywood glued together. On top of the base is the shell, which is made of (5) pieces of 0.5" plywood. Reinforcing the shell at the bottom are (4) 1 x 2 boards. Covering the inside of the shell is 0.75" foam insulation. On the front of the shell are (2) handles. The shell is secured to the base by a continuous hinge at the end opposite the handles.

Figure A-1


27.5"
Preheating Box
15.75"
33.25"
Handle
0.75"
Foam
Insulation
SCALE:
2 cm = 1"
15.25"
0.5"
1"
19.5"

Parts List

C & H Sales Company
2176 E. Colorado Blvd.
Pasadena, CA 91107
1-800-325-9465

12	Flexible Fiberglass Heaters	#HE8059	$1/ea.
1	Heating Tube	#HE8058	$5/ea.
2	20 cfm Panaflow 12V DC Fan	#DCB8652	$13/ea.
2	100 cfm Toyo 110 V AC Fan	#ACB8853	$10/ea.
1	6-figure 110V Counter	#EC8701	$10/ea.
2	1.5" Precision Vernier Dial	#VD8651	$3/ea.

Chromalox, Inc.
Distributor: Applebee-Church, Inc.
2375 John Glenn Drive—Suite 102
Atlanta, GA 30341
(404) 451-2747

2	Thermostats	$40/ea.

Ack Electronics
Local

1	8 Outlet Power Strip	$20
1	0.5 Amp 12V DC Power Supply	$12
3	Pigtail Cords	$8/ea.
1	Cutoff Microswitch	$1
1	Gray Electrical Wiring Box	$7
1	Small Relay: 6V DC/110V AC	$8

Radio Shack
Local

1	Photorelay	$40

Hardware Store
Local

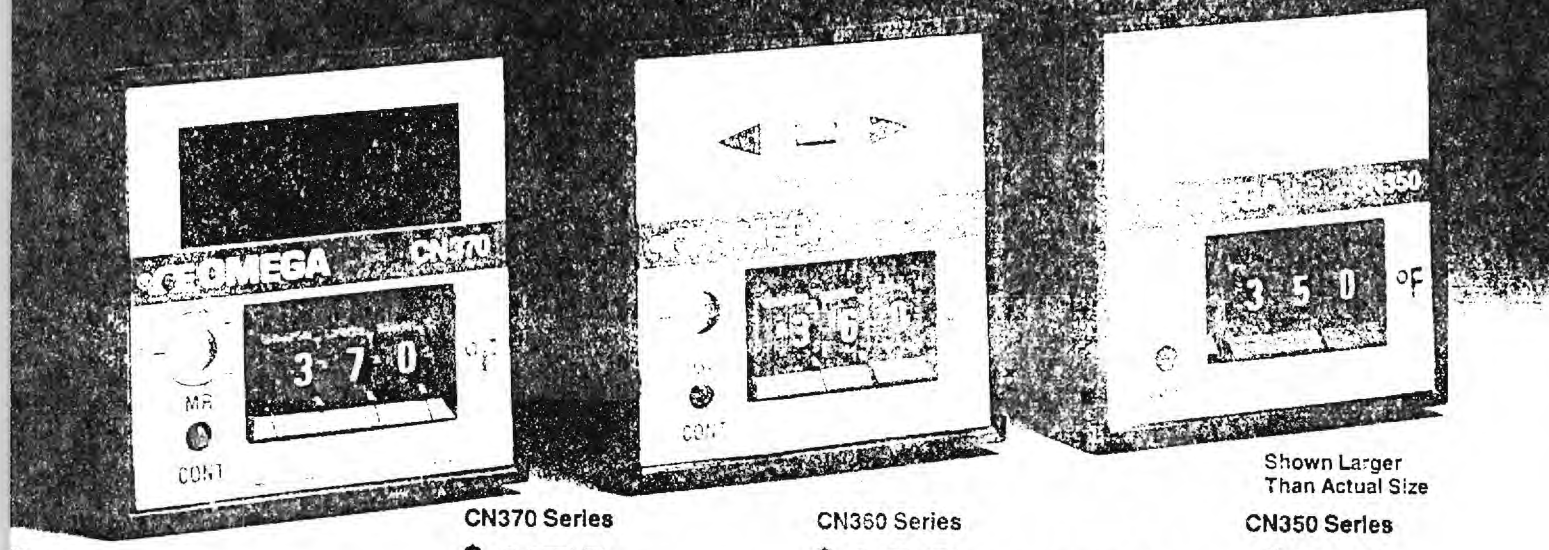
Hose mounting brackets, machine screws, wood screws, eye bolts, plumber's strapping, light bulb fixture, wire nuts, 1" x 1/2" wood strips.

Geotechnical Laboratory
Existing Parts

"START" and "STOP" buttons, 16 gauge wire, light bulb, 1/2" steel plate for preheating box, sheet metal for baffles in preheating box, large 110V AC relay.

Economical 1/16 DIN Temperature Controller

NEW!

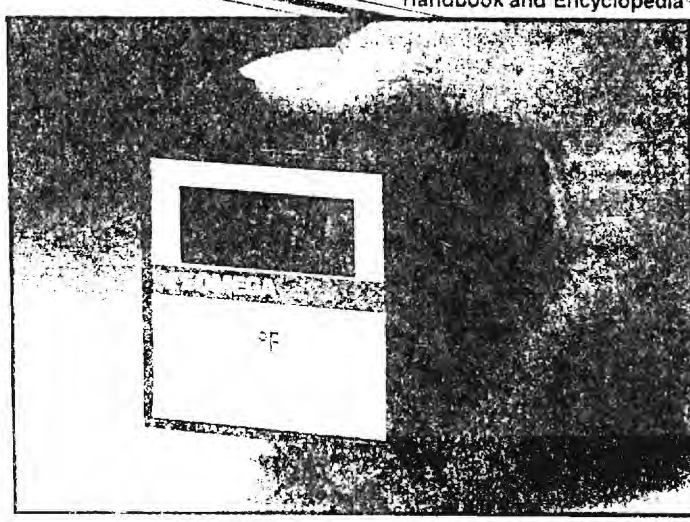


Shown Larger Than Actual Size

CN370 Series	CN360 Series		CN350 Series
$179	$139	1 YEAR	$99
Digital Display	Deviation Display	WARRANTY	Non-Indicating

Transition Probe Sold Separately. See Section A in the OMEGA Complete Temperature Measurement Handbook and Encyclopedia®.

- Economical, Easy to Use
- Small 1/16 DIN Panel Cutout
- Input Types: J, K, R, S Thermocouples and 100 Ohm Platinum RTD
- Fixed Proportional Band (4%) with Manual Reset
- Fixed Cycle Time: 30 s for Mechanical Relay and 3 s for dc Solid State Output
- User Convertible for Proportional or On-Off Control
- Digital, Deviation, and Non-indicating Models



Companion Panel Meter Model DP371. $129

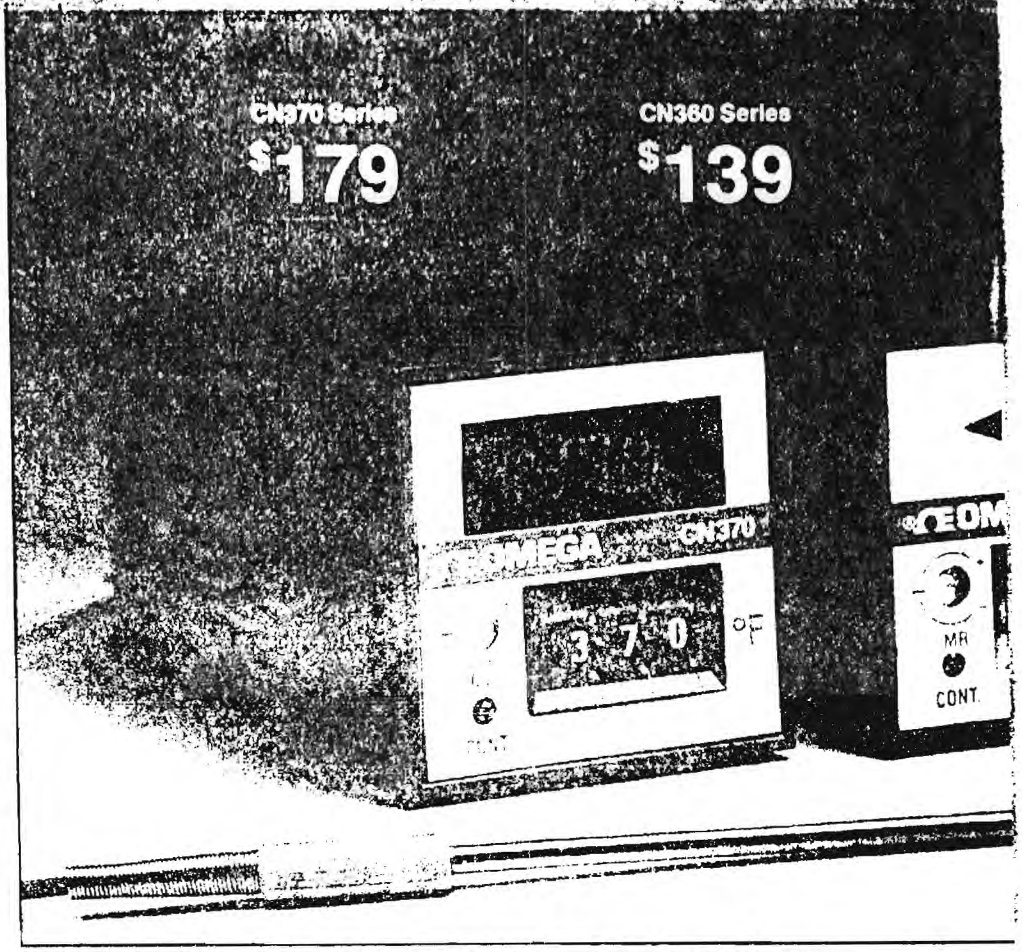
NEW!

OMEGACARE™ Extended Warranty Protection Plan		
Example:	CN370	CN360
Two Years	$32	$25
Three Years	$45	$35

Additional Warranty Protection Over the Standard 1-Year Warranty.

In-Stock for Off-the-Shelf Delivery!

OMEGA
An OMEGA Technologies Company
Box 4047, Stamford, CT 06907
Cable OMEGA FAX (203) 359 7700
1-800-TC OMEGA
In CT (203) 359-1660



Probes Sold Separately. See Section A of the Complete Temperature Measurement Handbook and Encyclopedia.

All models shipped with complete operator's manual.

The CN350, CN360, and CN370 Series controllers are designed for economical and easy use. Models are available with digital, deviation, or non-indicating display, for J, K, R, and S thermocouples or 100 ohm platinum RTD input. The small 1.9" square face (1/16 DIN) and short behind-panel depth (3.54") help save panel space and installation costs. All models have a digital thumbwheel for adjusting the setpoint.

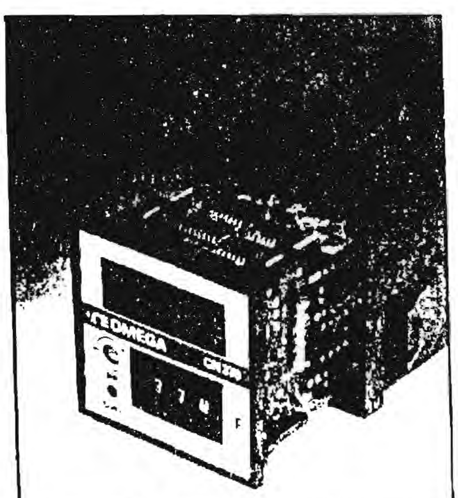
The CN370 Series models provide continuous digital display of the process temperature. The CN360 Series indicate whether the process temperature is within ± 1.5% full scale of the setpoint or above or below setpoint. The CN350 Series are non-indicating.

These controllers are time proportional with manual reset, and can be converted to ON-OFF control by changing internal jumpers. The proportional band is fixed at 4%.

Two types of output are available. A 2.5 Amp (SPDT) mechanical relay is for use with systems which can use a 30-second cycle time. With an external OMEGA solid state relay such as the SSR240A45, loads to 45 Amps can be accommodated.

For systems which require a faster cycle time, the dc solid state driver output should be used. This has a cycle time of approximately 3 seconds and can control high ac loads using a dc controlled solid state relay such as the OMEGA SSR240D45.

1/4 DIN Mounting Adaptor (not shown), part number CN9000-14. Price $10



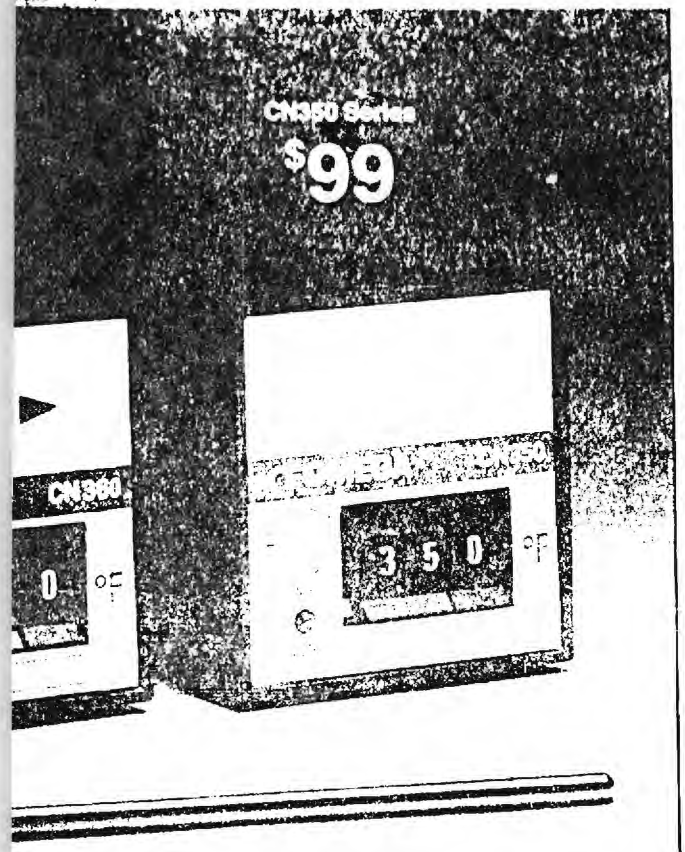
How to Order Relay Output Models*

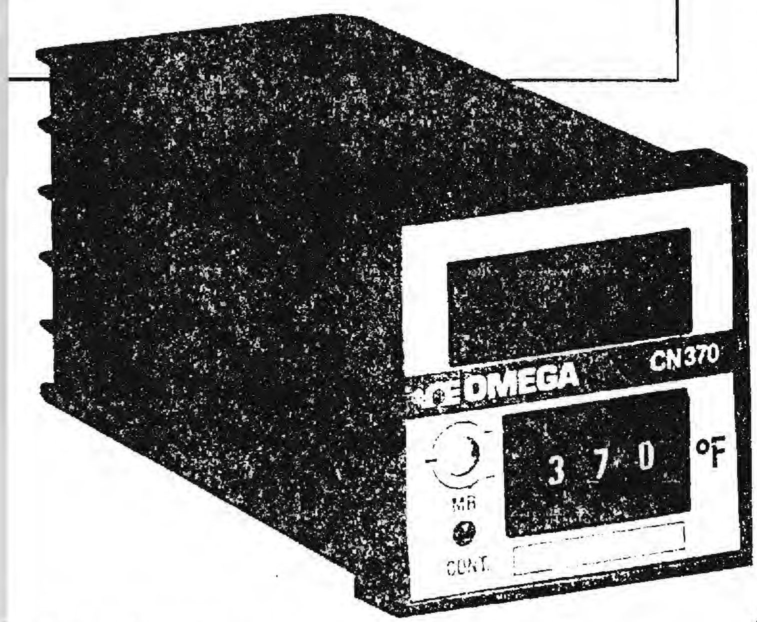
Sensor	Range	Indicating $179	Deviation $139	Non-Indicating $99
J	0 to 399°C	CN371-JC2	CN361-JC2	CN351-JC2
	0 to 499°F	CN371-JF3	CN361-JF3	CN351-JF3
	0 to 799°F	CN371-JF4	CN361-JF4	CN351-JF4
K	0 to 399°C	CN371-KC2	CN361-KC2	CN351-KC2
	0 to 999°C	CN371-KC5	CN361-KC5	CN351-KC5
	0 to 1199°C			CN351-KC6
	0 to 999°F	CN371-KF5	CN361-KF5	CN351-KF5
	0 to 1999°F			CN351-KF8
R	0 to 1699°C			CN351-RC7
	0 to 2999°F			CN351-RF9
S	0 to 1699°C			CN351-SC7
RTD	−99 to +99°C	CN371-P1C1	CN361-P1C1	CN351-P1C1
	0 to 99.9°C	CN371-P2CX	CN361-P2CX	CN351-P2CX
	0 to 399°C	CN371-P1C2	CN361-P1C2	CN351-P1C2
	0 to 399°F	CN371-P1F2	CN361-P1F2	CN351-P1F2
	0 to 799°F	CN371-P1F4	CN361-P1F4	CN351-P1F4

** How to Order DC Solid state output models: Replace the "1" in the three-digit model number with a "2." Example: CN372-JF3 instead of CN371-JF3, which is a relay model, no additional charge. Note that the same inputs and ranges are stocked for the solid state output models.*

Each controller is supplied with user's manual

HIGHLIGHTED MODELS STOCKED FOR FAST DELIVERY





Specifications

Accuracy: ± 1.5% FS + 1 digit (thermocouple input), ± 1.0% + 1 digit (RTD input)

Resolution: 1°F or C (P2CX range 0.1°C)

Output Types: (SPDT) Mechanical relay, 240 Vac, 2.5 A /resistive load (1 A inductive load)
Solid state voltage driver, 12 Vdc, 20 mA max—reverse action (N.O.) for heating

Power Supply: 115/230 Vac ± 10%, 50/60 Hz

Input: Three-wire RTD (Pt 100), 0.00385 Ω/Ω/°C
Excitation, 2 mA
Lead wire resistance, 2Ω max. per wire (approx. 190 ft of 20 gauge Cu wire)
Thermocouple, J, K, R*, S*
(*nonindicating model only)
Input resistance, 200 kΩ
Lead wire resistance, 100Ω max
Upscale protection circuit, Standard

Control Mode: Proportional band, 4% FS fixed; manual reset (MR), adjustable from front face
On/Off, Deadband/hysteresis, 0.3% FS fixed

Cycle Time: Mechanical relay, approx. 30 sec., fixed; dc solid state relay driver, approx 3 sec., fixed

Power Consumption: Approx. 3 VA

Operating Ambient Temp. Range: 5 to 45°C

Ambient Humidity Range: 90% RH max

Insulation Resistance: 500 V dc, 20 MΩ min. between input and power supply terminals

Connection: Screw terminals

Installation: Lock-in mounting type (no mounting hardware necessary)

Dimensions: 1.77"(45 mm) square (1/16 DIN) panel cutout, 1.88"(48 mm) square face, 3.54"(90 mm) depth behind panel

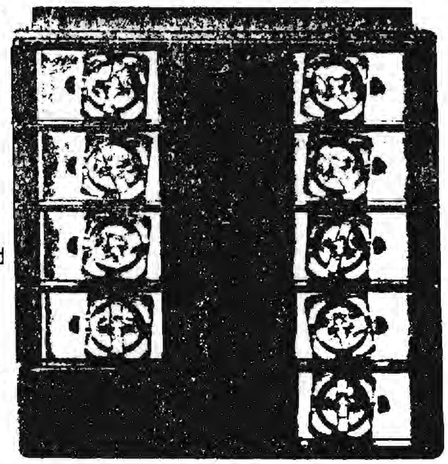
Panel thickness: 0.04-0.14" (1.0-3.5 mm)

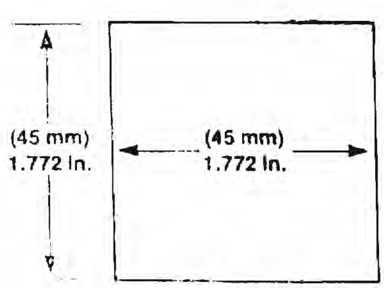
Weight: 0.463 lb (210 g)

Connection: Screw terminals

Companion Panel Meter

Screw Terminal Connections





Panel Cutout

1 YEAR

WARRANTY

OMEGA

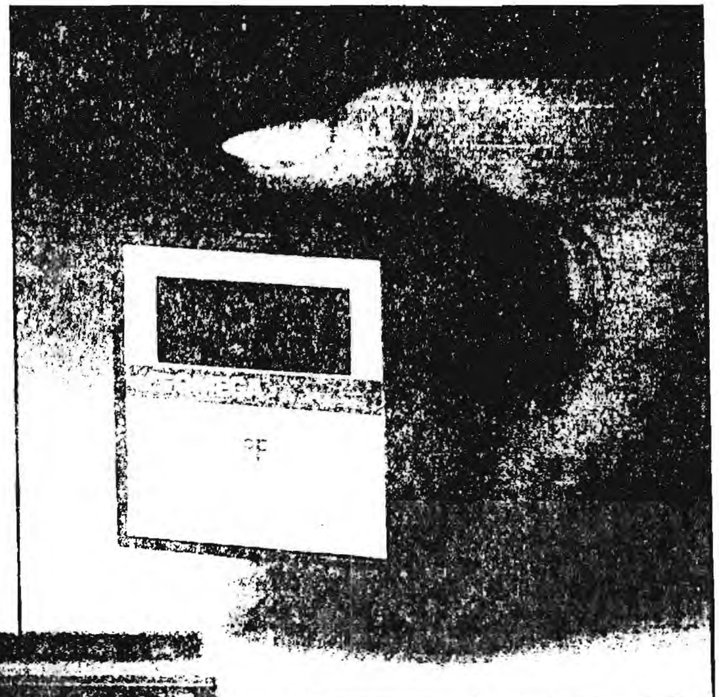
Miniature Digital Panel Thermometer
Model DP371

- Thermocouple and RTD Versions
- 1/16 DIN Size
- LED Display
- Economically Priced
- Quality Construction

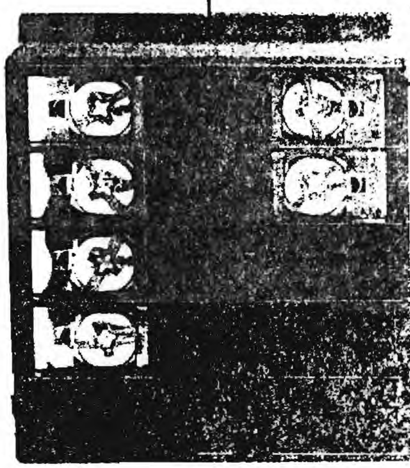
NEW!

The DP371 1/16 DIN miniature digital panel meters have a face size of only 1.9″ square. Models are available for Types J and K thermocouples and 3-wire 100 ohm platinum RTDs (α = 0.00385).

The small size and economical price make the DP371 the preferred solution where small frontal area, economy, and quality construction are important. The DP371 has an easy-to-read 3-digit LED display and features ±1.5% accuracy for thermocouple inputs, ±1.0% for RTD input.



1/4 DIN Mounting Adaptor (not shown), part number CN9000-14. Price $10.



Screw Terminal Connections

1 YEAR
WARRANTY

For extended warranties, ask your salesperson for details on OMEGACARE™.

All Models
$129
Includes Complete Operator's Manual

How to Order

Model Number	Price	Input Type	Range
DP371-JF3	$129	J Iron-Constantan	0 to 439°F
DP371-JF4			0 to 799°F
DP371-JC2			0 to 399°C
DP371-KF5		K Chromel-Alumel	0 to 999°F
DP371-KC2			0 to 399°C
DP371-KC5			0 to 999°C
DP371-P1F2		RTD 100 ohm	0 to 399°F
DP371-P1F4			0 to 799°F
DP371-P1C1			−99 to +99°C
DP371-P2CX			0 to 99.9°C
DP371-P1C2			0 to 399°C

Each panel meter comes with user's manual and integral panel mount locking device

HIGHLIGHTED MODELS STOCKED FOR FAST DELIVERY

Specifications

Accuracy: ±1.5% FS + 1 digit (thermocouple input), ±1.0% + 1 digit (RTD input)

Resolution: 1.0°F or C (P2CX range 0.1°C)

Input: Thermocouple: J, K
RTD: 100Ω platinum, α = 0.00385
Current, 2 mA; lead-wire resistance, 2 Ω max per wire (approx. 190 ft of 20 gauge copper wire) Cold junction temp. compensation range, 5 to 45°C; input resistance, 200 kΩ; external resistance, 100 Ω max

Power Supply: 115/230 Vac ±10%, 50-60 Hz

Operating Ambient Temp. Range: −10/+50°C

Operating Ambient Humidity Range: 90% RH max

Connection: Screw terminals

Installation: Lock-in mounting type (no mounting hardware necessary)

Dimensions: 1.88″ H x 1.88″ W (48 x 48 mm); 3.54″ (90 mm) depth behind panel

Panel Cutout: 1.77″ x 1.77″ (45 x 45 mm) per DIN

Panel Thickness: 0.04 to 1.4″ (1.0 to 3.5 mm)

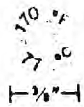
Weight: 0.463 lb (210 g)

Non-Reversible Labels

Indicator Dot Turns Black At Rated Temperature

Single Dot Round Labels (°C/°F) $5.50 pack of 30

Model No.	°F Range	Model No.	°F Range	Model No.	°F Range	Model No.	°F Range
TL-S-100	100	TL-S-190	190	TL-S-300	300	TL-S-410	410
TL-S-105	105	TL-S-200	200	TL-S-310	310	TL-S-420	420
TL-S-110	110	TL-S-210	210	TL-S-320	320	TL-S-435	435
TL-S-115	115	TL-S-220	220	TL-S-330	330	TL-S-450	450
TL-S-120	120	TL-S-230	230	TL-S-340	340	TL-S-465	465
TL-S-130	130	TL-S-240	240	TL-S-350	350	TL-S-480	480
TL-S-140	140	TL-S-250	250	TL-S-360	360	TL-S-490	490
TL-S-150	150	TL-S-260	260	TL-S-370	370	TL-S-500	500
TL-S-160	160	TL-S-270	270	TL-S-380	380	TL-S-543	543
TL-S-170	170	TL-S-280	280	TL-S-390	390		
TL-S-180	180	TL-S-290	290	TL-S-400	400		



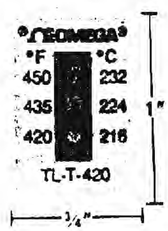
TL-S-170 shown

4 Dot Labels (°F only) $11.00 pack of 10

Model No.	Temperature Range °F				Model No.	Temperature Range °F			
TL-C-105	105	110	115	120	TL-C-290	290	300	310	320
TL-C-130	130	140	150	160	TL-C-330	330	340	350	360
TL-C-170	170	160	190	200	TL-C-370	370	380	390	400
TL-C-210	210	220	230	240	TL-C-410	410	420	435	450
TL-C-250	250	260	270	280	TL-C-465	465	480	490	500

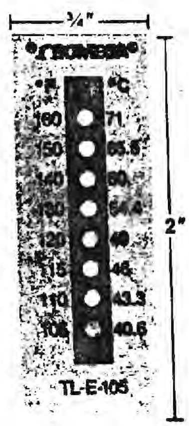
3 Dot Labels (°C/°F) $13.00 pack of 10

Model No.	Temperature Range °F			Model No.	Temperature Range °F		
TL-T-105	105	110	115	TL-T-300	300	310	320
TL-T-120	120	130	140	TL-T-330	330	340	350
TL-T-150	150	170	180	TL-T-360	360	370	380
TL-T-180	180	190	200	TL-T-390	390	400	410
TL-T-210	210	220	230	TL-T-420	420	435	450
TL-T-240	240	250	260	TL-T-465	465	480	490
TL-T-270	270	280	290				



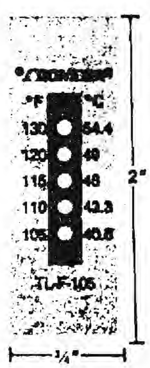
8 Dot Labels (°C/°F) $30.00 pack of 10

Model No.	Temperature Range °F							
TL-E-105	105	110	115	120	130	140	150	160
TL-E-170	170	180	190	200	210	220	230	240
TL-E-250	250	260	270	280	290	300	310	320
TL-E-330	330	340	350	360	370	380	390	400
TL-E-410	410	420	435	450	465	480	490	500



5 Dot Labels $19.00 pack of 10

Model No.	Temperature Range °F				
TL-F-105	105	110	115	120	130
TL-F-140	140	150	160	170	180
TL-F-190	190	200	210	220	230
TL-F-240	240	250	260	270	280
TL-F-290	290	300	310	320	330
TL-F-340	340	350	360	370	380
TL-F-390	390	400	410	420	435
TL-F-450	450	465	480	490	500



*All labels except TL-C Series show the °C equivalent to the °F rating.

Single Dot Labels

TL-S and TL-L labels are designed for low cost, single temperature operation. TL-S label are compact round labels, only ⅜" diameter. They are perfect for use in limited spaces. Also available, TL-L labels (shown below) provide the same, one dot temperature indication in a much larger label. This design is highly visible, for use in steam traps, hot power lines, etc., wherever such visibility is needed. TL-S labels are supplied in packages of 30, while TL-L labels are sold in packs of 10.

4-Dot Labels

TL-C labels feature four temperature ratings in a single, compact, round design. These labels are especially suited for use in areas with limited space. TL-C indicators are supplied 10 to a package.

3-Dot Labels

TL-T labels have three temperature ratings on a single label, which give the user more information about the maximum temperature of the label. Use these labels to bracket the maximum temperature. TL-T labels are supplied 10 to a package.

8-Dot Labels

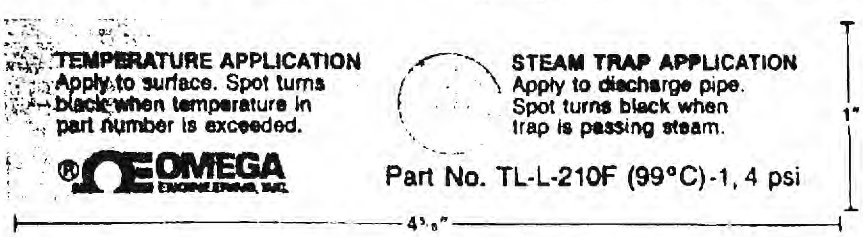
TL-E Labels provide the most value of the TL series labels. These labels have 8 different temperature ratings on a single label, which give the user the most information about the highest temperature reached. These indicators are supplied 10 to a package.

5-Dot Labels

TL-F labels have five temperature dots aligned in a straight line. This design gives the user the maximum temperature, with just a quick glance. The TL-F series labels are supplied 10 to a package.

Off-the-shelf Delivery!

Mix and Match Discounts	
Order Value	Discount
below $100	Net
$100 to 200	10%
$200.25 to 300	20%
$300.25 to 400	30%
$400.25 to 500	40%
over $500.00	Consult Sales Department

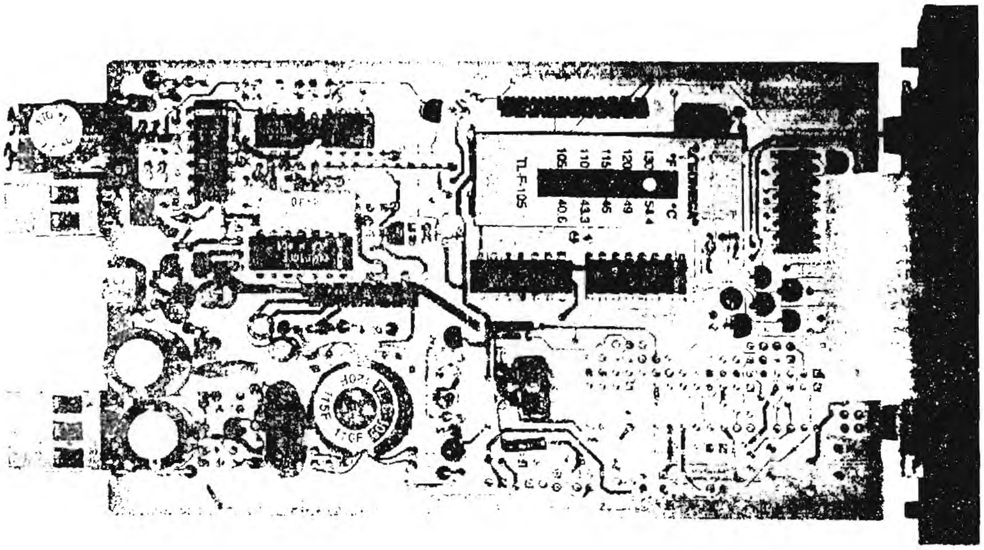


Steam Trap Labels

Model TL-L-210F

$25.50 pack of 10

TL Series Non-Reversible Temperature Indicators

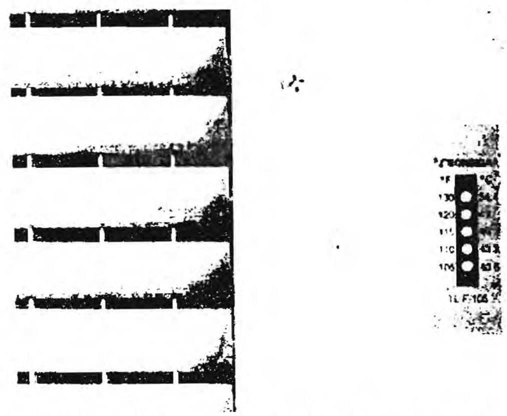


Measure Temperatures On Critical Circuits

Use TL labels to monitor the temperature of critical components on pc boards, in electronic circuits, where high temperatures can quickly and easily create havoc. The compact design makes them ideal for application in small areas, and the permanent nature of the labels means you don't need an operator watching the equipment around the clock.

Pipe Monitors To Warn Of Excess Heat

TL series indicators can be used in piping systems, to monitor for temperature extremes. The self-adhesive design makes them easy to apply and remove. And, these indicators are rugged, being both water and steam resistant. TL labels can be used in the harshest of environments with no loss in accuracy. The center indicator spot has a marked color change at the rated temperature, to make visual indication easier and faster.



Monitor Environmental Systems

In locations where temperature control is essential, the TL series labels provide a low cost means for monitoring HVAC and other environmental control systems. Perfect for monitoring critical systems, the TL series indicators with multi-temperature ratings bracket a temperature range, to give more information to the user.

OMEGA
An OMEGA Technologies Company
One Omega Drive Box 4047, Stamford, CT 06907
Telex 996404 Cable OMEGA FAX (203) 359-7700
1-800-TC OMEGA

All Labels In Stock For Fast Off-The-Shelf Delivery!

APPENDIX B

Owner's Manuals and Manufactures' Literature

for

Parts Used for LWT Machine and Temperature Control

FENWAL®

THERMOSWITCH®

Temperature Controllers

INSTALLATION INSTRUCTIONS

ATTENTION: *TO ASSURE SAFE AND PROPER PERFORMANCE READ THESE INSTRUCTIONS.*

GENERAL INFORMATION

The shell of each THERMOSWITCH unit contains the catalog number, the current rating, the temperature range and the contact arrangement.

The fifth digit of the catalog number describes whether contacts open or close on temperature rise. If contacts open on temperature rise (regular unit), the fifth digit of the catalog number is an even number such as 17000, 17002, etc. If contacts close on temperature rise (inverse unit), the fifth digit is an odd number such as 17021, 17023, etc.

UL Component recognized units will either have a "4" as the first digit (47002, etc.) or will bear the UL logo and utilize a 17000 series catalog number (17021, etc.).

If the fourth digit is other than "2" or "7" (such as 17021, 17071, etc.) it is compression operated. Inverse compression units are recommended if overshoots are to be encountered. Low temperature units can be overshot to 500°F and high temperature units (−100 to 600°F) overshot to 700°F for intervals not exceeding one hour.

INSTALLATION

Fenwal THERMOSWITCH® units are supplied in five basic head configurations – Cartridge, Block Head, Hex Head, Coupling Head and Circular Flange.

To avoid restricting shell expansion when making installations in solid metal blocks, a 5/8" diameter reamed hole for 5/8" units or a 13/16" diameter reamed hole for 13/16" diameter heavy duty units, is recommended. See specific controller style listing for additional installation instructions.

Cartridge [Style 1] (Includes moisture resistant high and low temperature units, A and C.) Hole should have short spline to receive the 1/8" diameter locating pin. This prevents the unit from rotating when the adjusting sleeve is turned. It may also be used for surface control if inserted into a Fenwal surface mounting block (Cat. No. 11100-2).

Block Head [Style 2] – is mounted in a similar manner to the cartridge type. If the unit is to be inserted into a reamed hole, two short pins should be mounted on either side of the hole. The pins should rest against the sides of the block head to prevent rotation of the unit.

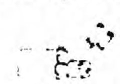
Hex and Coupling Head [Styles 3 and 4] – can be installed like any pipe fitting. See Table 1 for maximum torque value.

Circular Flange [Style 5] – Three holes in flange allow for easy mounting on any flat surface.

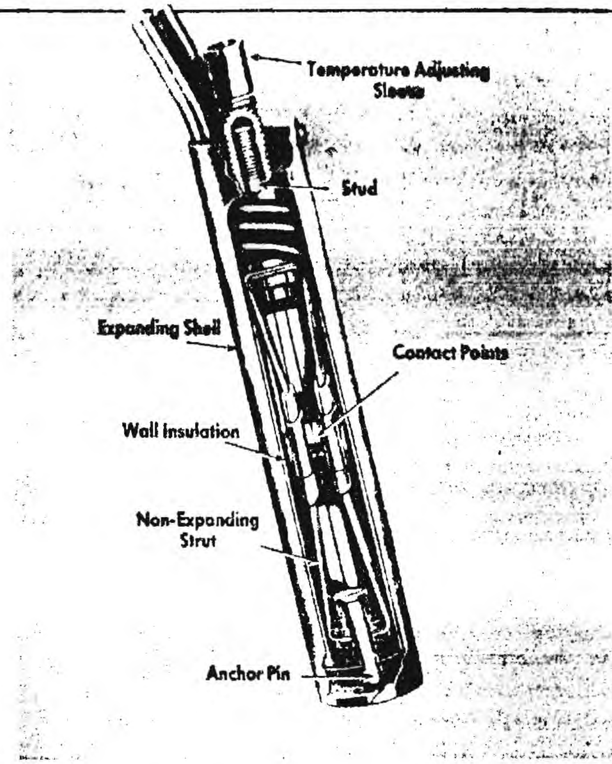
NOTE: *If the threaded units are installed in a pipe tee, the tee should be large enough to allow adequate circulation of the fluid around the temperature sensitive section of the unit.*

MOUNTING STYLES **Moisture Resistant Units**

(low temperature)



(high temperature)



NOTE: *Certain gases or liquids including water at elevated temperature could be corrosive and may also cause electrolytic action, which could severely shorten the life of the controller.*

The rate of corrosion or electrolysis is influenced by a great many system parameters such as chemical makeup and temperature of the solution, stray electric currents, etc. Consult the supplier of your chemicals or the factory for suggestions.

TABLE I – Torque

Max. Torque	THERMOSWITCH® Controller Types
35 ft. lbs.	5/8" Dia. Standard with N.P.T. *
70 ft. lbs.	13/16 Dia. Heavy Duty with N.P.T. **

* 4 ft. lbs.	*When Teflon tape lubricant is used.*
**8 ft. lbs.	

WARNING: *Excessive torque may change temperature settings.*

CAUTIONS!

DO connect THERMOSWITCH controller leads in series with the load and power supply.

DO be certain that there is sufficient but not excessive room for the installed THERMOSWITCH unit to expand in diameter and length.

DO use stainless steel heliarc welded thermowells, (Series 11100, 11200) or various platings which, may increase controller life where corrosion or electrolysis is suspect.

DO insulate head of the THERMOSWITCH unit where large external temperature variation may occur. This precaution is not necessary on the junction box type. (Series 17700, 17800).

DO prevent internal damage by mechanically presetting regular tension units (those with catalog number containing fourth digit other than 2 or 7) to approximate required elevated temperature before inserting into process. Preset by turning adjusting sleeve counterclockwise following the adjustment rate information shown on Table II, Page 2.

FENWAL

CAUTIONS (Continued)

DON'T immerse your unit in liquids or vapors unless it was specified for that job.

DON'T seal head with silicone materials.

DON'T exceed the ratings indicated on THERMOSWITCH unit shell.

DON'T thermally shield unit from medium being controlled.

DON'T *remove adjusting screw or turn adjusting screw in farther than necessary for desired operation. This action may permanently damage the unit and may void standard Fenwal warranty!*

DON'T oil your unit. Oil around adjusting screw will flow inside, contamining contacts.

DON'T allow moisture buildup in head cavity area of 37X0X0-000 Moisture Resistant Units. Where excessive moisture is a problem, specify Special Feature 01-982039-00X when ordering.

DON'T try to repair unit yourself.

DON'T handle unit with pliers or force it into position either by hand or tools, or apply excessive torque in tightening threaded units.

DON'T subject shell of unit to deformation.

DON'T over-torque threaded units.

TESTING AND ADJUSTMENT

The arrow on the head of THERMOSWITCH unit indicates direction to turn adjusting screw to **increase** temperature setting. Torque in excess of 15 inch pounds on adjusting sleeve will deform slot.

Each full turn of adjusting sleeve will change tempera ture the approximate number of degrees as follows:

TABLE II – Adjustment Rates for Thermoswitch Units

TENSION OPERATED		COMPRESSION OPERATED	
Catalog Series Number	**Approx. F° per full turn of adj. sleeve**	**Catalog Series Number**	**Approx. F° per full turn of adj. sleeve**
—	—	13121-1	1000
15050 to 16051	165	—	—
17000 to 17503	90-115	17020 to 17523	90-100
17700 to 17701	145	17720 to 17721	85
17702 to 17703	180	17722 to 17723	100-150
17800 to 17801	125	17820 to 17821	75
17802 to 17803	160	17822 to 17823	115
18000 to 18003	80-100	18020 to 18023	70-135
01-37X0X0-000	90		

After the THERMOSWITCH unit has been installed, final adjustment can be made by allowing the unit to operate for several cycles to permit the controlled system to stabilize and then adjust to desired temperatures. The system should then be cooled to ambient temperature, reheated and stabilized to check the setting.

To adjust a high temperature moisture resistant THERMOSWITCH unit (Cat. No. 01-370020-000) it is necessary to remove the seal cap. A screwdriver adjustment is then made internally. *Use caution when making adjustments at temperature extremes.*

Where extremely accurate temperature control is desired several readjustments may be necessary to stabilize the THERMOSWITCH control after which the adjustment will be maintained.

CONTACT PROTECTION

Capacitors are not required under average conditions. For smoother control at small loads, on D.C. applications or to prevent contact bounce due to vibration, the following table is recommended as a guide:

TABLE III – Contact Protection

VOLTAGE	SERVICE	CAPACITANCE MFD (non-polarized)
120VAC	Resistance	Non required
240VAC	Resistance	.1
120 or 240VAC or DC	Relays, Magnetic Contactors	.001 to .01
15–25VAC or DC	Relays	.02
120 or 240VAC	Motor	Use Relay

NOTE: *Capacitors should be wired in parallel with thermostat lead connections. Capacitors should be rated for a minimum of 600VDC with 120VAC circuits and a minimum of 1000VDC for 240VAC circuits.*

TESTING TEMPERATURE SET POINT

*The **Set Point Temperature** is the temperature at which the **contacts** on a THERMOSWITCH unit just **"make"** (close).* All THERMOSWITCH units are set at room temperature (75°F ± 15°F) unless otherwise specified in which case they are factory preset at any specified temperature within listed temperature range and setting tolerance of THERMOSWITCH unit.

If customer requires testing of temperature set point, it is recommended that testing devices can be used similar to those at the factory. An ideal thermal installation may require that the THERMOSWITCH unit be located as near as possible to the heat source. Testing the temperature set point of a THERMOSWITCH unit in an application or under conditions where heat source is remotely located from THERMOSWITCH unit, or when ambient temperature conditions are far below or above 75°F, may give misleading results. In some cases, this has led to rejection of units which were actually within proper setting tolerance. Therefore we recommend the use of a Fenwal Model 80001-0 Test Kit, for testing temperature set points on Fenwal THERMOSWITCH units.

For customers who wish to build their own test equipment we recommend that you contact your nearest Fenwal Representative. He is equipped to give you further guidance in setting up a good thermal test system.

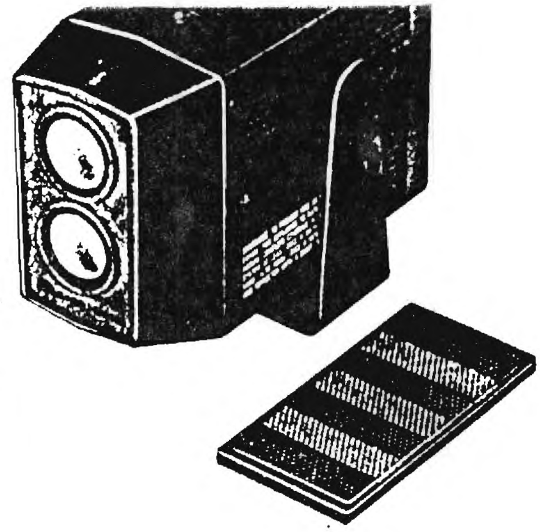
LIMITED WARRANTY STATEMENT

Fenwal Incorporated represents that this product is free from defects in material and workmanship, and it will repair or replace any product or part thereof which proves to be defective in workmanship or material for a period of twelve (12) months from the date of purchase but not to exceed eighteen (18) months after shipment by the seller. For a full description of Fenwal's LIMITED WARRANTY, which among other things, limits the duration of warranties of MERCHANTABILITY and FITNESS FOR A PARTICULAR PURPOSE and EXCLUDES liability for CONSEQUENTIAL DAMAGES, please read the entire LIMITED WARRANTY on the Fenwal Quotation, Acceptance of Order and/or Original Invoice which will become a part of your sales agreement. Defective units should be returned to the factory, Ashland, Massachusetts, shipment prepaid. Fenwal Incorporated will repair or replace and ship prepaid.

FENWAL INCORPORATED
Division of Kidde Inc
KIDDE
400 Main Street Ashland, Massachusetts 01720 (617) 881-2000
1.10 S 100M 11/86 Printed in U.S.A.

PULSED BEAM

INFRARED PHOTORELAY/ALARM



PLEASE READ BEFORE USING THIS EQUIPMENT

CAT. NO. 49-307

CUSTOM MANUFACTURED FOR RADIO SHACK, A DIVISION OF TANDY CORPORATION

SAFE HOUSE®

FEATURES

Your Radio Shack Infrared Photorelay/Alarm will sound a tone any time its invisible pulsed infrared beam is broken. The Alarm can be used across a doorway or any opening up to fifty feet wide.

The infrared receiver is virtually unaffected by room lights, indirect sunlight, or other light sources, so accidental tripping from these sources is unlikely.

The many special features listed at right make the Alarm easy to use in many different applications.

To avoid problems, we urge you to read this manual completely before you install or use the Alarm.

THIS PRODUCT IS UL LISTED UNDER STANDARD NUMBER 1023 HOUSEHOLD BURGLAR ALARM SYSTEM UNITS.

ADDITIONAL ALARM FEATURES

- Alignment indicator to aid in installation and testing
- Relay contacts for activation of external devices, such as a security dialer, or for connection to the alarm loop of an alarm system
- Sensitivity control to adjust for different width openings
- Three-position alarm mode switch to determine the type of sounding when the alarm is tripped. This allows you to use the alarm for an "open-door" announcer for your home or business.
- Terminals for optional battery back-up power supply
- 12-volt DC power terminals for connection of an optional external sounding device
- Circuit breaker protection — no fuse to replace

No alarm system can prevent an intruder from entering your home or office. Alarm systems are designed to deter intruders and give a warning if one does attempt to enter the protected area. Careful planning and installation will help you achieve this goal.

THE INFRARED PHOTORELAY/ ALARM SHOULD BE USED WITH U.L. LISTED ACCESSORIES, ONLY.

For your own protection, we urge you to record the serial number of this unit in the space provided below. The serial number is located in the units label.

Serial Number ____________________

The Alarm sends out an invisible beam of infrared light. This beam bounces off of the reflector and returns to the receiver in the Alarm.

As long as the path of the beam is not interrupted, nothing happens. However, if a person (or anything else) moves through the beam and breaks the path back to the receiver, the Alarm will sound.

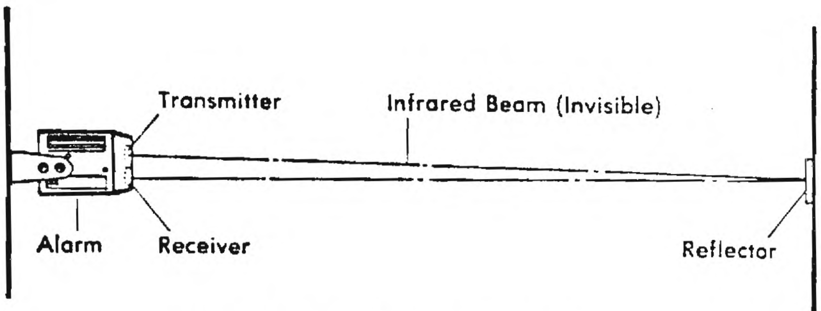


Figure 1 How the Alarm Works

CONTROLS AND CONNECTIONS (Operation Summary)

For more detailed information, see "Installation" and "Operation" in this manual.

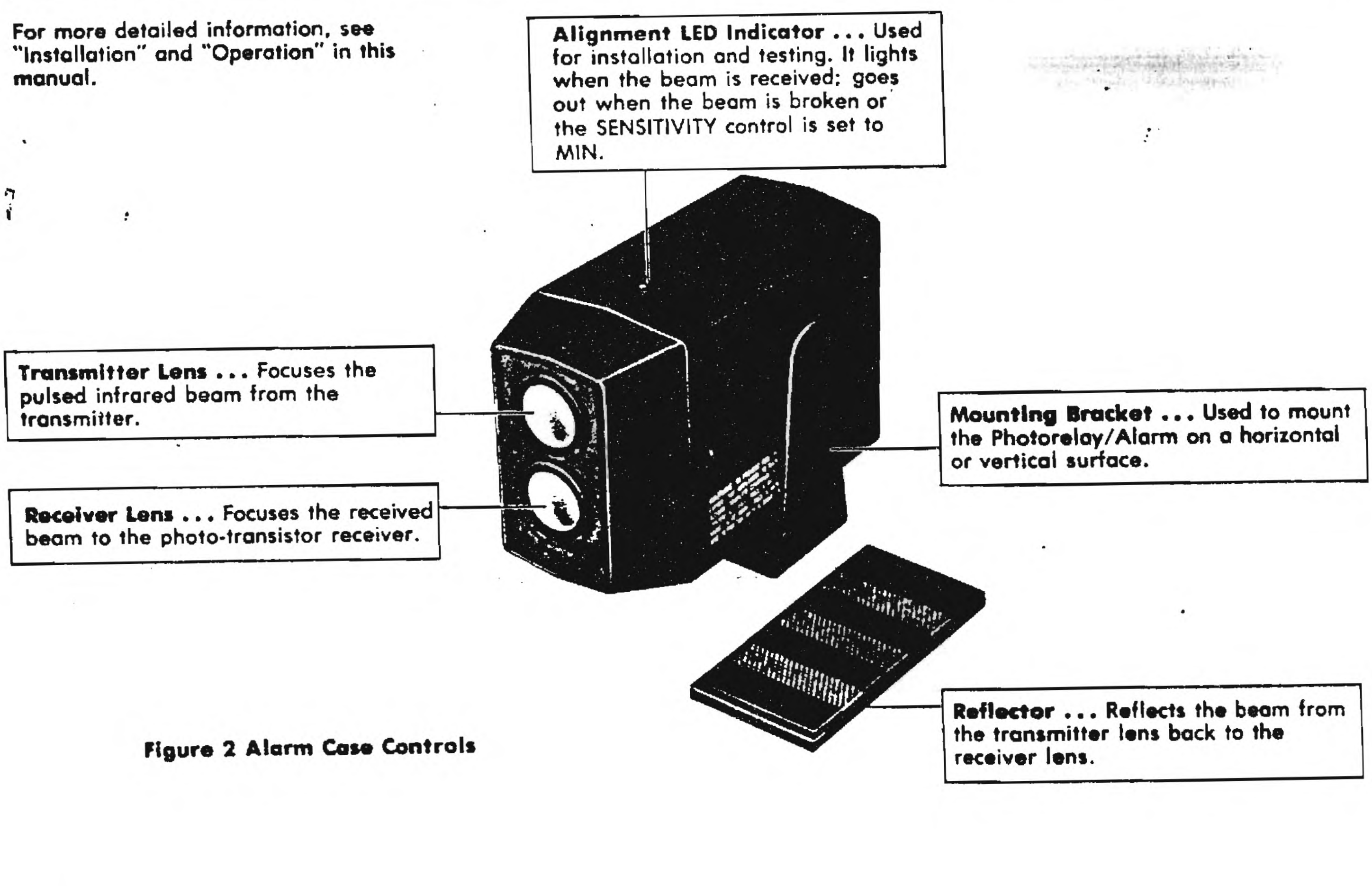


Figure 2 Alarm Case Controls

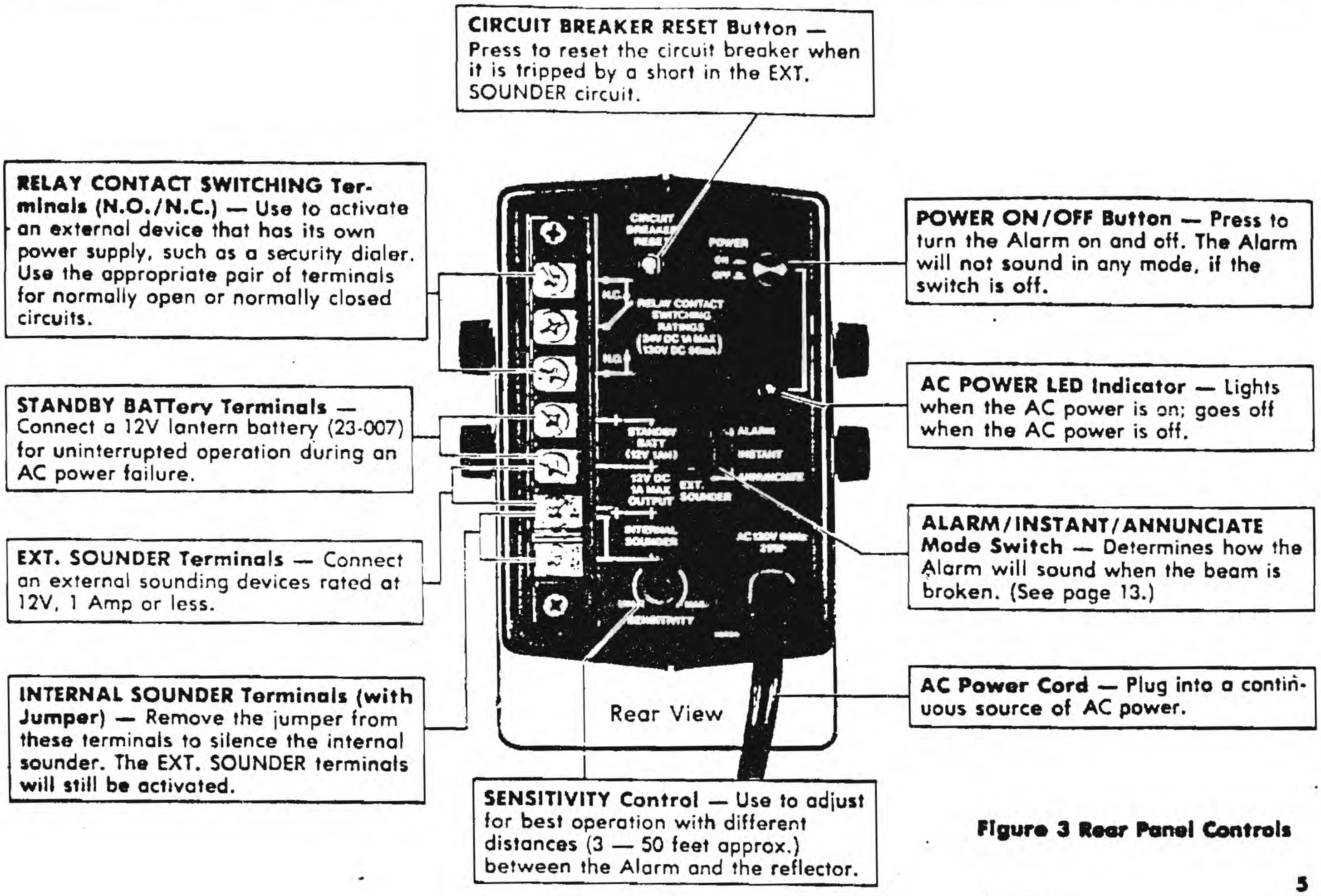


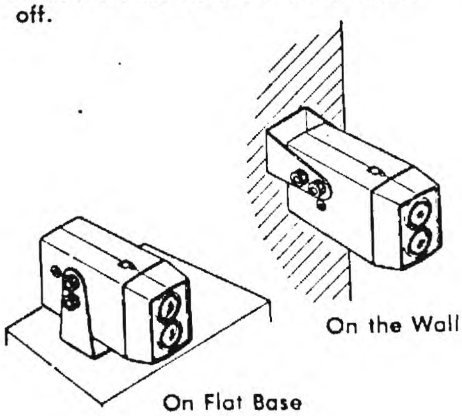
Figure 3 Rear Panel Controls

INSTALLATION

CHOOSING A LOCATION

For most applications, the Alarm and reflector are mounted on parallel walls so that the beam is aimed across a doorway or other opening. However, the mounting brackets also allow mounting on horizontal surfaces such as a desk or counter top. **The Alarm beam must be aimed squarely at the reflector.**

Be sure there is an AC outlet close to the mounting location of the Alarm. The AC outlet should always be on (not controlled by a wall switch) so the Alarm will not be accidentally turned off.



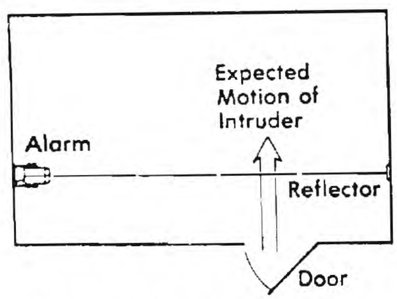


Figure 5 Positioning Example

The mounting height of the two units (Alarm and reflector) should be low enough to prevent someone from crawling under the beam but high enough to prevent false tripping by pets or small children. Both units must be the same height.

Avoid locations that will expose either unit to direct sunlight. This could cause false tripping or cause damage to either of the units.

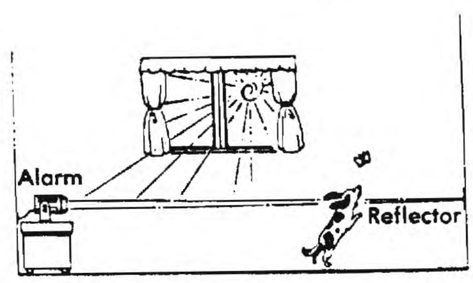


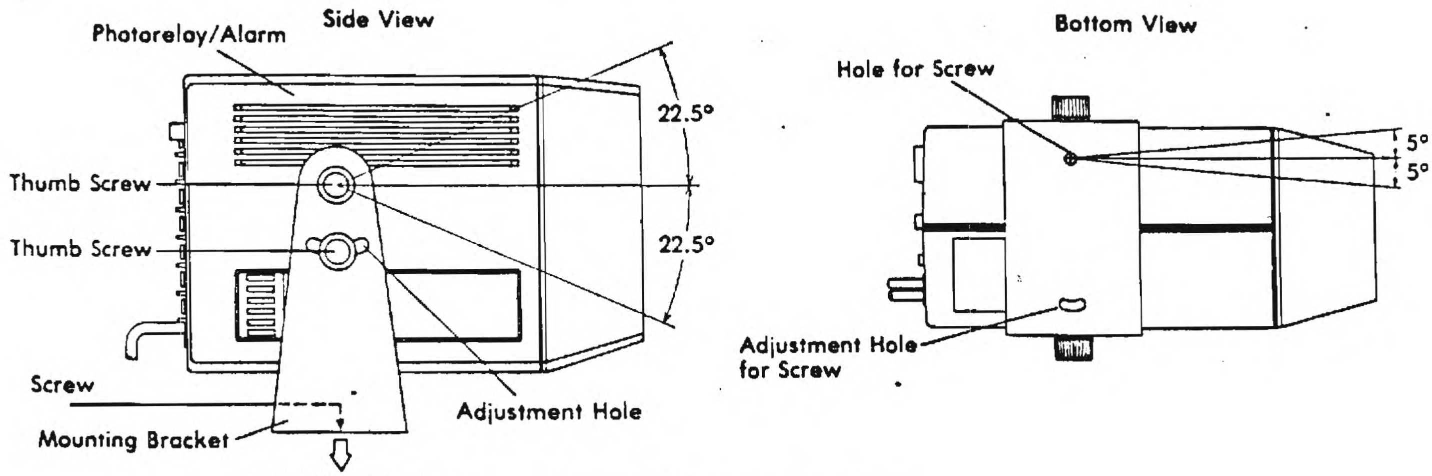
Figure 6 Causes of False Alarm

After a suitable location has been selected, mount the Alarm as described below. **Do not fully tighten the adjustment screws until you have performed "Beam Alignment" as described on page 9.**

1. Using the bracket as a template, mark the position for the two screw holes.

2. Mount the bracket using the two supplied screws. The slot in the bracket allows a slight adjustment of the Alarm (+/– 5°) after the screws are inserted.

3. Using the four thumb screws (supplied), attach the Alarm to the bracket. The bracket allows adjustment of the Alarm angle (+/– 22.5°) before the thumb screws are securely tightened.



To Wall or Flat Base

Figure 7 Mounting the Alarm

MOUNTING THE REFLECTOR

Be sure the reflector is mounted at the same height as the Alarm on a surface that is parallel to the Alarm mounting surface.

1. Using one half of the bracket as a template, mark the position for the two wood screws holes.

2. Mount the bracket using the two supplied wood screws.

3. Remove the protective paper from the adhesive strips on the back of the reflector and attach the reflector to the other half of the bracket, as shown.

4. Attach the reflector half of the bracket to the part of the bracket mounted on the wall (step 2); use two of the supplied machine screws.

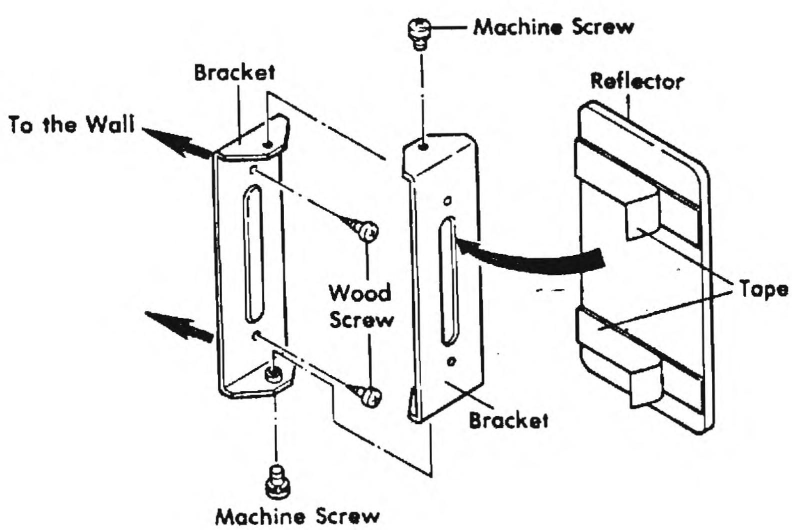


Figure 8 Mounting the Reflector

BEAM ALIGNMENT

1. Before plugging in the Alarm, set the mode switch to INSTANT and the POWER button to OFF.

2. Turn the SENSITIVITY control fully clockwise.

3. Plug the power cord into a constant (not switched) source of AC power.

4. Press the POWER button to ON. If alignment is incorrect the Alarm will sound and the ALIGNMENT INDICATOR will be off.

5. Adjust the angle of the Alarm and/or reflector until the sound stops and the ALIGNMENT indicator lights. Firmly tighten the adjustment screws on both mounting brackets.

SENSITIVITY CONTROL ADJUSTMENT

Proper adjustment of the SENSITIVITY control will assure reliable performance of the Alarm and minimize the chance of false soundings.

1. Set the mode switch to INSTANT and POWER button to ON.

2. Turn the SENSITIVITY control fully counterclockwise; the ALIGNMENT indicator will go off.

3. Turn the SENSITIVITY control clockwise until the ALIGNMENT indicator comes on; then turn it a little further in the same direction.

4. With the mode switch still set to INSTANT, break the beam by walking between the Alarm and reflector; the Alarm should sound.

Note: If the SENSITIVITY control is set to MAX or close to MAX, it is possible that your Photorelay/Alarm will not sound if a person in highly reflective clothing walks through the beam.

If you want to add an external sounder, battery back-up power, or a device to be activated by the Alarm (such as a security dialer or counter), see page 10. Otherwise proceed to "Operation" on page 13.

CONNECTION OF EXTERNAL DEVICES

The Alarm will function properly as installed but the addition of one or more of these optional, external devices will increase its dependability and versatility.

Back-up Battery

If it is important to have uninterrupted operation of the Alarm, ever during an AC power failure, you may connect a 12-volt lantern battery (23-007) to the STANDBY BATT terminals on the Alarm. Be sure to observe correct polarity (+ and –).

With the back-up battery installed, the Alarm will automatically switch to battery power in the event of an AC power failure.

The battery should last for about 2 years if there are no AC power failures. The battery should power the Photorelay/Alarm for about 10 hours during a power failure if there is no alarm sounding. If the Photorelay/Alarm sounds during a power failure, the battery will last for about 2 full 5 minute's alarm cycles.

Test the battery regularly by unplugging the AC power cord and breaking the beam. To save battery power, set the mode switch to INSTANT; then plug in the AC cord.

External Sounder

If you want the Alarm to sound a tone at a location other than the place it is installed, you may connect an external sounder to the EXT. SOUNDER terminals. **The sounding device must be rated at 12V, 1 Amp or less.**

Note: If you do not want any sound when the beam is interrupted (when using the Alarm as a counter, for example), remove the INTERNAL SOUNDER jumper and make no connection to the EXT. SOUNDER terminals.

The Alarm may be used in two way to activate external devices.

First, if you are using an alarm device that has normally open (N.O.) or normally closed (N.C.) alarm-type activation terminals (such as a perimeter alarm, motion detector, or security dialer), connect the terminals to the corresponding terminals on the Alarm.

be programmed to call a police station unless there is a number expressly for this purpose. Contact your local police for specific regulations.

If the device does not have activation terminals, use the N.O. terminals on the Alarm as a switch to connect an external power source to the external device. **The rating of the external device must not exceed 12V, 1amp.**

rupted the N.C. and/or N.O. terminals will be tripped. It is likely that alarm type devices will continue to operate even after the sound stops. Devices using the N.O. terminals as a power switch, however, will turn off when the sound is stopped.

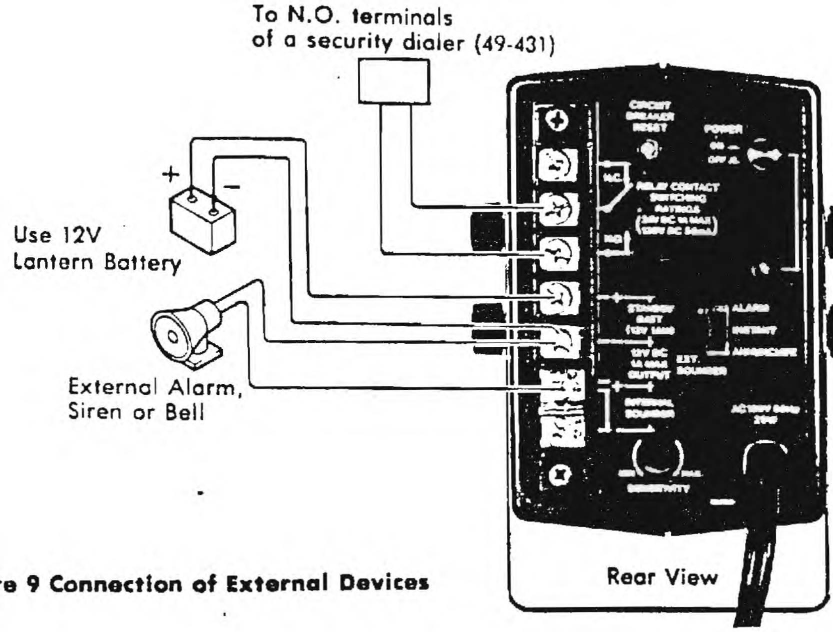


Figure 9 Connection of External Devices

RESTRAINING THE AC POWER CORD (FOR USA MODELS ONLY)

A cable clamp is supplied to help prevent the attachment plug of the unit from being accidently dislodged from the AC receptacle. Use it as follows:

1. Duplex (2) receptacles with decorator cover (Normally used in living areas of the home). See Figure 10.

a) Turn off power to receptacle at fuse box or breaker panel.
b) Insert units attachment plug into receptacle.
c) Remove #6 screws securing decorative cover to receptacle.
d) Remove plastic clamp from units packing and slip plastic clamp over line cord plug.
e) Secure line cord with plastic clamp and receptacle cover to receptacle by reinstalling #6 screw as shown in Figure 10.
f) Restore power at fuse box or breaker panel and test unit.

2. Quad(4) receptacle box. (May be used in basements, garages or workshops in the home or elsewhere). See Figure 11.

a) Turn off power to quad receptacle box at fuse box or breaker panel.
b) Insert units attachment plug into receptacle.
c) Remove #8 securing corner of box cover closest to the attachment plug.

CAUTION: Do not remove #6 screw between receptacles or receptacle may detach from box cover.

d) Remove plastic clamp from units packing and slip plastic clamp over line cord near attachment plug.
e) Secure line cord with plastic clamp and box cover to box by reinstalling #8 screw shown in Figure 11.
f) Restore power at fuse box or breaker panel and test unit.

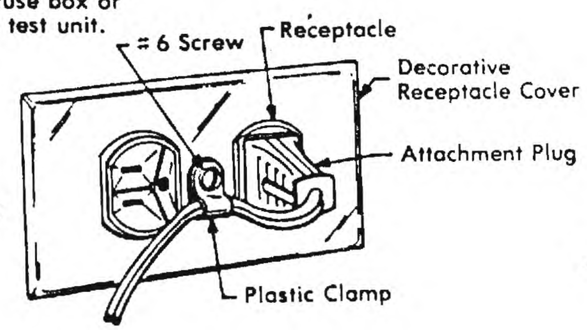


Figure 10

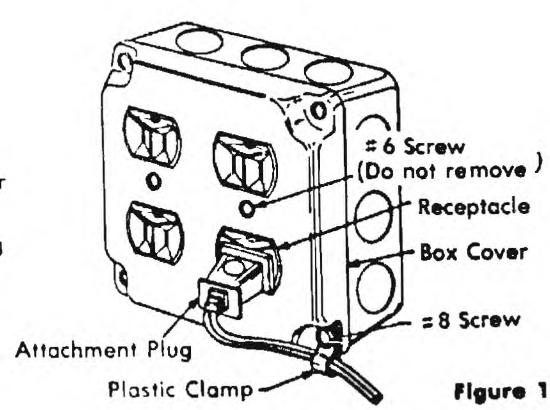


Figure 11

After you have installed the Alarm and reflector, operation of the Alarm will depend on the setting of the ALARM/INSTANT/ANNUNCIATE mode switch. Below is a brief description of each mode along with some suggested uses.

The volume level of the sounder will be greater in the alarm mode than in the instant or annunciate modes.

ALARM:

In the alarm mode the Alarm will sound for approximately five minutes when the beam is interrupted. It continues to sound whether or not the path of the beam is restored. The sound may be stopped, however, by changing the setting of the mode switch or by setting the POWER switch to OFF.

After five minutes the Alarm will stop sounding and reset so that it may sound again.

Note: The Alarm will stop and reset, even if the beam is still interrupted at the end of the 5-minute cycle. The beam must be completed and then interrupted again, in order to set off the Alarm again.

INSTANT:

In this mode the Alarm will sound when the beam is broken but will silence immediately when the path of the beam is restored.

Use this mode in a home or business to warn you when someone enters or leaves a room. This is also the best mode to use when you are installing and testing the Alarm.

ANNUNCIATE:

In the annunciate mode the Alarm only sounds two short tones, regardless of how long the beam is interrupted.

This mode can be used for the same applications as the instant mode; the advantage is that the tone does not continue if someone stands between the Alarm and reflector for a long time.

TESTING/MAINTENANCE

In most applications the Alarm will be "tested" in every day use. But you may test the unit at any time by turning on the power and interrupting the beam. Use the instant or annunciate mode during testing.

To test battery power, unplug the AC cord and interrupt the beam. To conserve battery power, turn off the Alarm as soon as you have confirmed proper operation (and re-connect the AC power).

LIGHTNING

Lightning damage is uncommon, but it can occur in electronic devices. A lightning strike near, or directly to, the power line may cause an excessive surge of voltage that can damage the product. If you are concerned about it or live in an area with frequent and/or severe electrical storms, we suggest that you purchase a surge protector, such as our cat. no. 61-2790 or 61-2785 to help prevent against damage from power line surges.

IF YOU HAVE PROBLEMS

We hope you don't . . . but if you do, try these suggestions:

If the problem is false alarms . . .

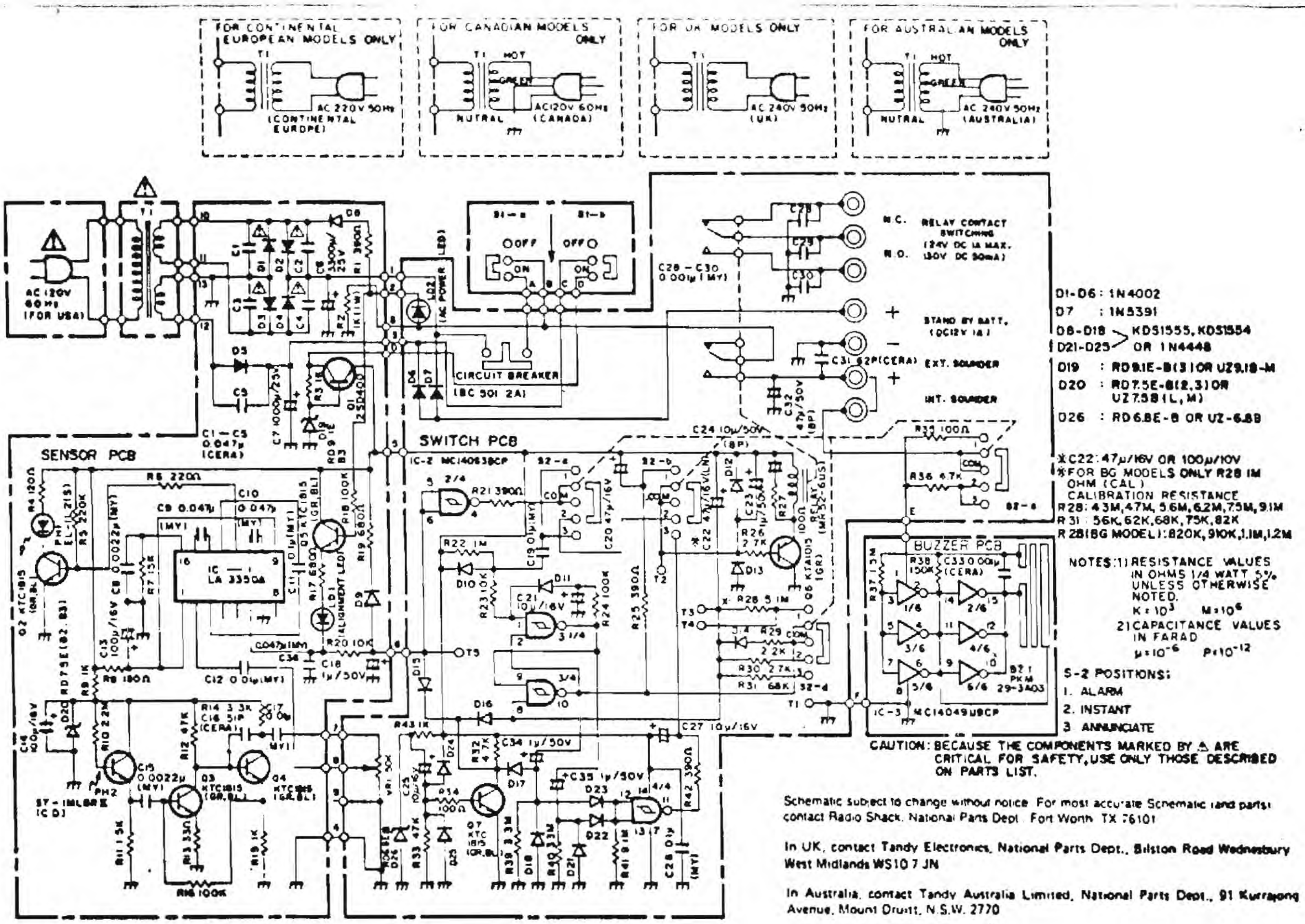
1) Check for the distance of the Alarm and the reflector. The distance of the Alarm and the reflector should be within 3 — 50 feet. If set out of this range, the Alarm will operate erratically.
Adjust the SENSITIVITY control so that the false alarm stops. Then follow the procedures on page 9.

2) Check if the surface of the reflector is parallel to the front of the Alarm. If not, re-position the Alarm and/or reflector, then follow the procedures on page 9.

If none of above hints helps, return your Alarm to your nearest Radio Shack. We'll get it back in working condition ASAP!

SPECIFICATIONS

- Power Requirement:
  120 Volts AC 60 Hz, 29 Watts
  (240 Volts AC 50 Hz, 29 Watts for units purchased in UK or Australia)
- Power Consumption:
  Current Consumption: 65 mA Typical
  Standby Battery Current Consumption (at 12 Volts DC AC failed): 75 mA Typical
- Effective Distance: Approx. 2.7 Feet (0.8m) — 50 Feet (15 m)
- Light Source:
  Infrared LED (pulse-modulated)
- Receiver:
  Infrared sensitive photo-transistor
- Reflector Angle Error: 10° Max.
- Automatic Reset Time:
  ALARM ... 5 Minutes Typical, 4-6 Minutes Limit
  ANNUNCIATE ... 5 Seconds Typical (2 seconds sounding, 1 seconds resting, and 2 seconds sounding again), 3—7 Seconds Limit
- Internal Sounder Sound Pressure Level:
  ALARM ... Min. 85 dB at 10 Feet
  INSTANT/ANNUNCIATE ... 70 dB Typical at 10 Feet
- Input Terminal: Back up Battery 12 Volts DC (1A)
- Output Available For:
  12V DC 1A MAX OUTPUT: 12 Volts DC, 1A, maximum. Do not use a bell or siren that exceeds these ratings.
  RELAY SWITCHING CONTACT RATING Terminals: 24 Volts DC, 1A, maximum. 130 Volts, DC, 50 mA. Use these terminals as a switch to turn on a device (such as a Security Telephone Dialer) that has its own power source. It must not exceed the power rating above. There is no power available from these terminals.



Schematic subject to change without notice. For most accurate Schematic (and parts) contact Radio Shack, National Parts Dept., Fort Worth, TX 76101

In UK, contact Tandy Electronics, National Parts Dept., Bilston Road Wednesbury West Midlands WS10 7 JN

In Australia, contact Tandy Australia Limited, National Parts Dept., 91 Kurrajong Avenue, Mount Druitt, N.S.W. 2770

RADIO SHACK LIMITED WARRANTY

This security product is warranted against manufacturing defects in material and workmanship for ninety (90) days from the date of purchase from Radio Shack company owned stores and authorized Radio Shack franchisees and dealers. Within this period Radio Shack will repair the security product without charge for parts and labor. Simply bring your Radio Shack sales slip as proof-of-purchase date to any Radio Shack store.

This warranty does not cover damage or failure caused by or attributable to Acts of God, abuse, misuse, improper or abnormal usage, faulty installation, improper maintenance, lightning or other incidence of excess voltage, or any repairs other than those provided by a Radio Shack Authorized Service Facility, or transportation costs.

Radio Shack is not responsible or liable for indirect, special, or consequential damages arising out of or in connection with the use or performance of the product or other damages with respect to loss of property, loss of revenues or profit, or costs of removal, installation or reinstallation.

EXCEPT AS PROVIDED HEREIN, RADIO SHACK MAKES NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Some states do not allow the limitation or exclusion of incidental or consequential damages and some states do not allow limitation or exclusion of implied warranties; therefore, the aforesaid limitation(s) or exclusion(s) may not apply to the purchaser.

There will be charges rendered for repairs to the product made after the expiration of the aforesaid ninety (90) day warranty period.

This warranty gives you specific legal rights and you may have other rights which vary from state to state.

We Service What We Sell

11 83

RADIO SHACK
A Division of Tandy Corporation
Fort Worth, Texas 76102

APPENDIX C

Static Compaction Beam Samples

Data Sheets

Mix Design Worksheets

MIX DESIGN

Volume of mold = (15/12)(3/12)(3/12) = 0.078 ft^3

Optimum AC = 5.70%

AC =5.5 Unit Wt. = 142.7

AC =6.0 Unit Wt. = 144.5

Interpolate: AC = 5.70 Unit Wt. = 143.4 pcf

Total Weight of Beam = (0.078 ft^3)(143 pcf) = 11.18 lbs = 5078 g

For a Beam of 5078 g,

AC = 5078(0.057) = 289.4 g

Lime = 5078(0.01) = 50.8 g

Aggregate = 5078 - (289.4 + 50.8) = 4737.8 g

Break into two layers:

AC = 144.7 g/layer

Lime = 25.4 g/layer

Aggregate = 2368.9 g/layer

	BUFORD 007		BUFORD 89		BUFORD MID		CUMMING	
Sieve	%FR	GRAMS	%FR	GRAMS	%FR	GRAMS	%FR	GRAMS
3/4								
1/2	3	24						
3/8	48	379						
#4	46	363	72	171	5	43	1	5
#8	1	8	24	57	22	188	14	68
—8	2	16	4	9	73	622	85	416
		790		237		853		489

DEPT. OF TRANSPORTATION 88043
STATE OF GEORGIA
OFFICE OF MATERIALS AND RESEARCH
ASPHALTIC CONCRETE DESIGN REPORT

CHECKED BY
1.
2.
3.
4.

PROJECT NO.
COUNTY
DATE
REPORT ON ASPHALTIC CONCRETE E
MIX ID NO.

GENERAL DATA

MATERIALS	SIZE, GRADE OR TYPE (CODE)	% USED WITH LIME	% USED W/OUT LIME	GROUP	SOURCE CODE NO.	SOURCE/LOCATION
AGGREGATE	007	33		IIA	102C	Ga. Marble @ Buford
	089	10		IIA	102C	" "
	M10	36		IIA	102C	" "
	777	20		II	099F	Ga. Marble @ Cumming
MIN. FILLER						
ASPH. CEMENT	AC30					Amoco 30 Fulco
HYDR. LIME		1.0				Approved Source
ADDITIVE						

DESIGN MIX PROPERTIES

(WITH HYDR. LIME ONLY)

ASPH. CTN. (%)	THEOR. SPEC. GRAV.	ACTUAL SPEC. GRAV.	VOIDS IN MIX (%)	MIX DENSITY (LBS/FT)	VOIDS IN MIN. AGGR. (%)	AGGR. VOIDS FILLED (%)	STABILITY (LBS)	FLOW
4.50	2.469	2.252	7.9	140.5	18.6	57.5	2780	9.7
5.00	2.451	2.269	7.4	141.6	18.4	59.8	2860	9.7
5.50	2.434	2.287	6.0	142.7	18.2	67.0	2900	10
6.00	2.417	2.316	4.2	144.5	17.6	76.1	2890	11.5
6.50	2.399	2.324	3.1	145.0	17.8	82.6	2750	12.8

Check Wts

20 5.5
21 6.0

(WITH LIQUID ADDITIVE ONLY)

AGGREGATE GRADATIONS

GRADATION-% PASSING EACH SIEVE / AGGR. SIZE	007	089	M10	ADJ. M10	Cumming 777	ADJ. 777	LIME	COMB. GRAD.
1 1/2								
1								
3/4	100							100
1/2	97	100						99
3/8	49	100	100	100	100	100		83
4	3	28	95	95	99	99		59
8	2	4	74	73	85	85		45
16			59	58	68	68		35
30			49	48	47	47		28
50			37	36	22	22		18
100			25	23	9	8	100	11
200			14	12	4	3	100	6

REMARKS

DIAMETRAL TENSILE SPLITTING

PROPERTY	ANTI-STRIP AGENT LIME	ANTI-STRIP AGENT LIQUID
CONDITIONED PSI		
CONTROL PSI		
RETAINED STAB. (%)		

JOB MIX FORMULA CRITERIA

WITH H. LIME	OPTIMUM AC (%)	FILM THICK (μ)
50 BLOW	5.70	
75 BLOW		
WITH LIQ. ADD.		
AGGR. EFF. GRAV.		2.642

Asphalt Mix Design Summary Sheet

STATIC COMPACTION OF A BEAM

Date: 2/28/89 Technician: Anderson Mix: GADOT 88043

Mixing:

	Lift #1	Lift #2
Wt. of Aggregate:	2351	2360
Wt. of Lime:	24	24
Wt. of Asphalt Cement:	145	145

Compaction:

Testing Machine: Tinius-Olsen, Hydraulic

Compression Mold: 15" long, removable bottom

Temp. of Mix at Compaction: 260 deg. F

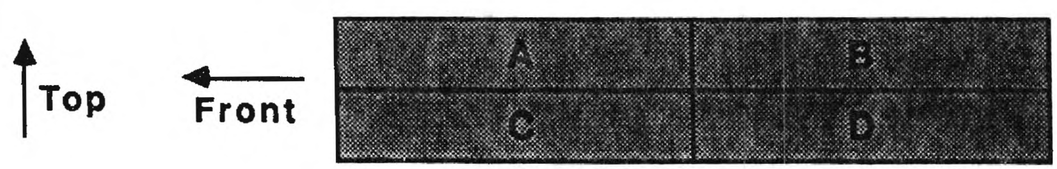
Maximum Load Applied: 81,200 lbs

Elapsed Time at Max. Load: 1 min 24 sec

Elapsed Time at Removal of Max. Load: 6 min 24 sec

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	5007	2749	5016	2.209	137.8
Segment A	-----	-----	-----	----	------
Segment B	-----	-----	-----	----	------
Segment C	-----	-----	-----	----	------
Segment D	-----	-----	-----	----	------



Comments or Deviations in Procedure: Aggregate Oven: 410 deg. F; Mold Oven: 390 deg. F

STATIC COMPACTION OF A BEAM

Date: 7/13/88 Technician: Anderson Mix: GADOT 88043

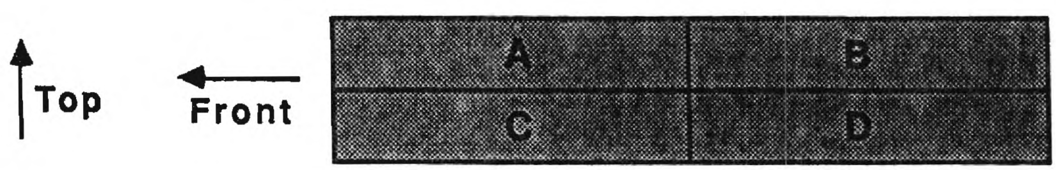
Mixing:	Lift #1	Lift #2
Wt. of Aggregate:	------------	------------
Wt. of Lime:	------------	------------
Wt. of Asphalt Cement:	------------	------------

Compaction:

Testing Machine:	Tinius-Olsen, Screw-Type
Compression Mold:	18" long, with 3" spacer
Temp. of Mix at Compaction:	-----------------
Maximum Load Applied:	85,000 lbs
Elapsed Time at Max. Load:	N/A
Elapsed Time at Removal of Max. Load:	N/A

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	4984	2785	------	2.266	141.4
Segment A	1239	687	------	2.246	140.2
Segment B	1232	676	------	2.216	138.3
Segment C	1143	640	------	2.272	141.8
Segment D	1173	650	------	2.243	140.0



Comments or Deviations in Procedure: Mold was too hot; severely scorched asphalt; compression head difficult to keep level; removed beam by dissasembling mold.

STATIC COMPACTION OF A BEAM

Date: 1/25/89 Technician: Anderson Mix: GADOT 88043

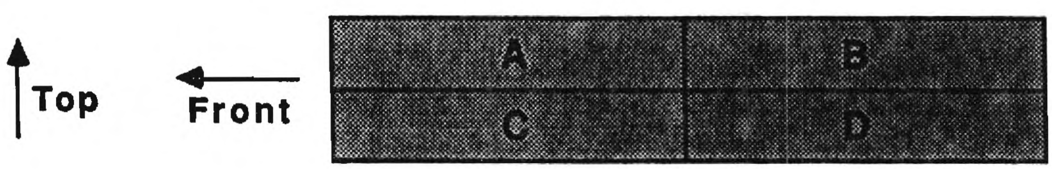
Mixing:	Lift #1	Lift #2
Wt. of Aggregate:	------------	------------
Wt. of Lime:	------------	------------
Wt. of Asphalt Cement:	------------	------------

Compaction:

Testing Machine:	Tinius-Olsen, Hydraulic
Compression Mold:	15" long, fixed bottom plate
Temp. of Mix at Compaction:	-----------------
Maximum Load Applied:	76,500 lbs
Elapsed Time at Max. Load:	3 min 10 sec
Elapsed Time at Removal of Max. Load:	10 min 0 sec

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	5013	2779	5023	2.234	139.4
Segment A	1201	668	1202	2.249	140.3
Segment B	1210	663	1211	2.208	137.8
Segment C	1189	663	1190	2.256	140.8
Segment D	1192	656	1194	2.216	138.3



Comments or Deviations in Procedure: This was the first sample removed from the mold by extrusion

STATIC COMPACTION OF A BEAM

Date: 2/7/89 Technician: Anderson Mix: GADOT 88043

Mixing:

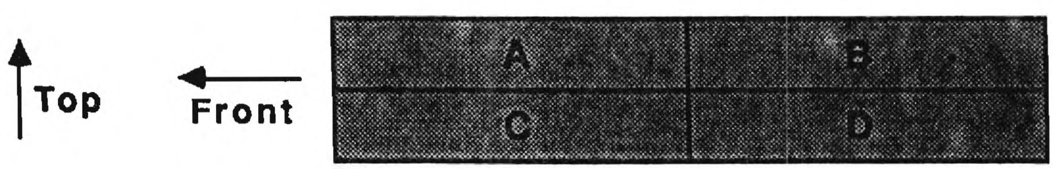
	Lift #1	Lift #2
Wt. of Aggregate:	2362	2361
Wt. of Lime:	25	25
Wt. of Asphalt Cement:	144	144

Compaction:

Testing Machine:	Tinius-Olsen, Hydraulic
Compression Mold:	18" long, with 3" spacer
Temp. of Mix at Compaction:	260 deg. F
Maximum Load Applied:	78,500 lbs
Elapsed Time at Max. Load:	5 min 23 sec
Elapsed Time at Removal of Max. Load:	12 min 23 sec

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	5013	2770	5024	2.224	138.7
Segment A	1160	644	1162	2.194	136.9
Segment B	1253	684	1255	2.194	136.9
Segment C	1277	709	1280	2.236	139.6
Segment D	1089	595	1092	2.191	136.7



Comments or Deviations in Procedure: ______________________

STATIC COMPACTION OF A BEAM

Date: 2/22/89 Technician: Anderson Mix: GADOT 88043

Mixing:

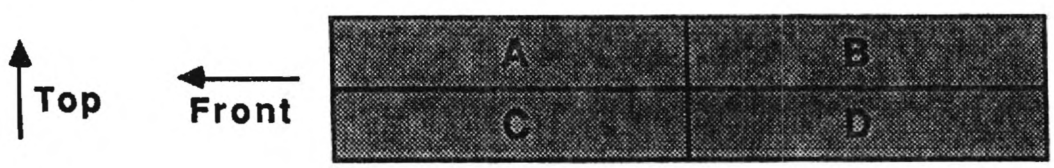
	Lift #1	Lift #2
Wt. of Aggregate:	2363	2360
Wt. of Lime:	24	24
Wt. of Asphalt Cement:	135	135

Compaction:

Testing Machine:	Tinius-Olsen, Hydraulic
Compression Mold:	15" long, removable bottom
Temp. of Mix at Compaction:	230 deg. F
Maximum Load Applied:	81,500 lbs
Elapsed Time at Max. Load:	4 min 23 sec
Elapsed Time at Removal of Max. Load:	11 min 12 sec

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	5002	2759	5009	2.223	138.7
Segment A	1136	622	1139	2.197	137.1
Segment B	1176	649	1177	2.227	139.0
Segment C	1155	634	1158	2.204	137.5
Segment D	1306	728	1308	2.252	140.5



Comments or Deviations in Procedure: ______________________

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STATIC COMPACTION OF A BEAM

Date: 2/23/89 Technician: Anderson Mix: GADOT 88043

Mixing:

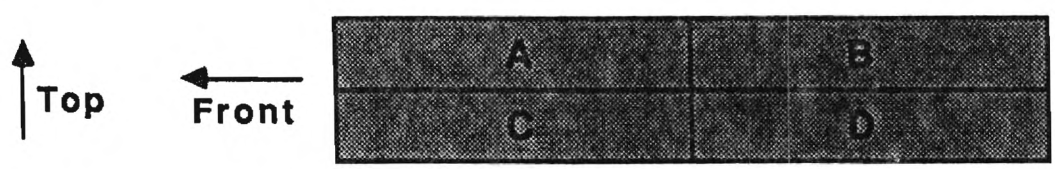
	Lift #1	Lift #2
Wt. of Aggregate:	2361	2360
Wt. of Lime:	24	24
Wt. of Asphalt Cement:	136	136

Compaction:

Testing Machine:	Tinius-Olsen, Hydraulic
Compression Mold:	15" long, removable bottom
Temp. of Mix at Compaction:	245 deg. F
Maximum Load Applied:	81,700 lbs
Elapsed Time at Max. Load:	1 min 35 sec
Elapsed Time at Removal of Max. Load:	8 min 10 sec

Specific Gravity:

	Air Wt.	H_2O Wt.	SSD Wt.	Bulk SG	Unit Wt.
Total Beam	4991	2744	5003	2.209	137.9
Segment A	1232	676	1234	2.208	137.8
Segment B	1175	646	1178	2.209	137.8
Segment C	1187	650	1190	2.198	137.2
Segment D	1173	645	1176	2.209	137.8



Comments or Deviations in Procedure: